HISTORY OF SCIENCE AND TECHNOLOGY –A NEW PERSPECTIVE

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Background Paper

Introduction to the HIST Book Series

Rajiv Malhotra and Jay Patel

Outline

This chapter is intended to provide a background to the *History of Indian Science and Technology* (HIST) project. By describing the rationale and purpose of the HIST series, we hope to awaken the reader to the full implications of the series outside its scholastic usage. This chapter consists of the following sections:

I. Rationale behind Infinity Foundation's HIST projects.
II. Indian contributions to science and technology
III. Infinity's book series on *History of Indian Science & Technology*

Section I: Rationale behind Infinity Foundation's Projects

Non-Western Knowledge Systems:

Modern Western technology has produced amazing achievements, but we must analyze the wider implications of such technologies and their notions of progress. These technologies often bring huge negative consequences that seem negligible in the short-term. We need to dispassionately investigate whether there are alternative technologies that offer more sustainable progress for all, rather than only the privileged.

In search for such technologies, traditional knowledge or 'local knowledge' provides a pointer. Traditional knowledge is the technical, social, organizational and cultural collective memory of human responses to the complexities of life, and is a part of the great human experiment of survival and development. Western criteria should not be the sole benchmark by which non-Western cultural knowledge is evaluated. While Western intellectual discourse has marginalized the term 'traditional' with the connotation of 'pre-modern' in the sense of 'primitive' or 'outdated', many of the traditional sciences and technologies were quite advanced by 'modern' standards as well as better adapted to unique local conditions and needs than their later substitutes.

These traditional folk and elite sciences are intertwined with their distinct ancient cultures and worldviews. Unfortunately, modernization has homogenized the categories, reducing diversity of worldviews in ways similar to the destruction of biodiversity. Using contrived hegemonic categories – such as science verses magic, technology verses superstitions, modern versus tradition – European colonizers systematically exterminated or undermined

local traditional science, technology and crafts. Aside from intellectual arrogance, there was a profit motive to this – as evidenced by Britain's conquest of Indian textile and metallurgical know-how.
Many anthropologists who have recently worked with so-called 'primitive' peoples have been surprised to learn of some of their highly evolved and sophisticated technologies. The term 'Traditional Knowledge System' was thus coined as a scientific system which has its own validity, as a supplement to 'modern' science.

Infinity Foundation's vision is to correct the portrayal of Indian civilization in a wide range of academic disciplines, including the history of science, history of ideas, world history, anthropology and culture. Besides India's philosophical and cultural legacy, its scientific heritage needs to be understood in order to give its people a realistic sense of their place in the world. This aim is not inspired by chauvinism, but by the need to better comprehend the genius of Indian Civilization, and by the need to provide a fresh and vital voice in the global community. The foundation has undertaken the challenge of compiling a 20-volume reference series titled, *The History of Indian Science and Technology*:

<u>Reason 1:</u> Western science and technology by itself will be inadequate in the future:

The rapidly-expanding, globalizing economy is built largely on Western lifestyles and is homogenizing human 'wants' in unachievable ways. Across the world, people are being forced to accept that progress, success and modernity are synonymous with Westernization. Those 'left behind' are made to feel like failures when measured against this standard. However, this promise of universal Westernization is simply unachievable. There are several reasons why:

1 The capital required for universal Western-style development simply does not exist in the world, and the trickle down effect of free markets is too slow to reach the bottom tiers where most people live.

2 Western civilization depends upon inequality (in the form of cheap labor) and massive natural resources, which is eventually unsustainable sociologically or ecologically. The global capitalist system in some ways stands in contradiction to individual rights, which it promotes in theory. For instance, a free market of labor would involve free movement of workers across international borders, but this would threaten the artificially high wages of Western citizens.

3 The bulk of labor in the non-Western world is outside the framework of globalization and development. Significantly, today less than 10 per cent of India's labor works in the 'organized sector', namely as employees of a company. The remaining 90 per cent comprises freelances, contract laborers, private entrepreneurs, and so on. Many of them still practice traditional, non-Westernized trades. Indian colonial law continues to render much of their work illegal, making them highly vulnerable to exploitation, corruption, and abuse. The descendants of India's traditional knowledge workers, who built massive cities, who

had highly developed and researched technologies, and who dominated world trade for centuries, are today de-legitimized in their own country. Many of today's poor *jati*s, such as workers in textile, masonry and metal works, were at one time the empowered guilds that supplied the world with highly-prized manufacture.

4 The Western economic development model demands relentless growth to sustain equity valuations in the financial markets, and yet growth cannot be indefinite once population stabilizes. A steady state economy in zero-growth equilibrium would devastate the wealth of the West, since all financial valuations are predicated on growth. Thus, there is a vested interest for the West to push its technologies without looking to the extended future. Even if the world's six billion persons (anticipated to grow to ten billion by the middle of this century) were to magically achieve Western lifestyles, this would be temporary because of limits to the planet's natural resources. When Gandhi was asked whether he would like India to develop a lifestyle similar to England's, his reply may be paraphrased as follows: The British had to plunder the Earth to achieve their lifestyle. Given India's much larger population, it would require the plunder of many planets to achieve the same.

5 The West controls the institutions, standards, socio-economic categories and laws (such as the notions of ’property’ and ’justice’ which originated from Biblical concepts) on which the global system is based. The non-West is thus inherently disadvantaged. The West will be able to accommodate a relatively small percentage of non-Westerners as honorary Westerners, to serve as middlemen in managing and containing the non-Western masses, in exchange for enjoying Western privileges.

6 Western lifestyle is built on inequality. Cheap labor, cheap natural resources, and blights like industrial pollution and environmental degradation must be exported to the third world facilitate this lifestyle. For Western lifestyle to exist, poverty and deprivation must also exist somewhere in the world. Many in the West show awareness and concern for the ‘Other’ but are unable to identify these problems as natural implications of Western lifestyle.

7 Many traditional knowledge systems are relevant to economic planning today, because they are eco-friendly, sustainable, labor-intensive, rather than capital intensive. Implementation of traditional technologies should be done in parallel with top down ‘modern’ scientific development. For example:

- Water is one of the more serious problem areas of India and many other parts of the world. There was an ancient Indian system of *talab*s (water tanks) in every village. They were designed to collect and store rainwater for irrigation and for drinking. It was a function of the village *panchayat* to maintain and administer these water tanks. However, under colonial rule, village governance was subverted or abandoned, since the goal was to maximize tax collection through a network of British-appointed “district collectors”. As native social structures were abandoned, many *talab*s went

into disuse or misuse. Today, satellite pictures show only traces of what was once a massive network of man-made lakes.

- This indigenous system scores over modern dams that are centrally managed and possible ecological hazards. In parts of Tamil Nadu and Rajasthan, many of these old *talab*s have been excavated and revived, alleviating, to a degree, water scarcity.

- Indians were the first to develop steel, and the famous Delhi Iron Pillar is the world's oldest extant rust-free sample of steel, having lasted 16 centuries. Leading metallurgists are now engaged in research to understand the old processes and their implications for developing corrosion-resistant iron for specific applications like concrete reinforcement bars.

- Many healing systems from non-Western sources, including Indian medical systems, are now being revived. These complement modern medicine. Besides physical healing systems, such as Ayurveda, there is growing interest in Indian systems of mind-management, including forms of yoga and meditation. These have been incorporated in the West in the form of stress management or motivational training.

- Less than five per cent of the known classical Indian texts (in Sanskrit, Tamil, etc.) have ever been translated. What might be the insights and knowledge systems of our ancestors that lie hidden in these?

It is, therefore, imperative that we study, preserve, and revive traditional knowledge systems. India's scientific heritage needs to be highlighted so as to replace Eurocentric historiography with an honest history of ideas.

<u>Reason 2:</u> Multi-polar historical perspectives must replace Eurocentrism:

Since the dawn of history, different peoples have contributed to different branches of science and technology, often through interactive contacts across cultures separated by large distances. This interactive influence is becoming clearer as the vast extent of pre-colonial global trade and cultural migration is being properly understood by researchers. However, one finds a mainly Eurocentric perspective in the teaching of the history of science. Typically, it starts with Greece, neglecting the influences of others upon Greece. Then it 'fast forwards' many centuries into 1500 CE to claim modern science as an exclusively European triumph, neglecting the influence of others (especially India) on the European Renaissance and the Enlightenment. The European Dark Ages are presumed to be dark worldwide, when, in fact, other regions saw innovation and prosperity. In fact, Europe was at the peripheries, until the conquest of America in 1492.

With the entrenchment of colonialism, the contribution made by others, including India, was ignored. The British colonizers could never accept that Indians were highly civilized as far back as the third millennium BCE when the British were still in a barbarian stage. Such

acknowledgment would destroy Europe’s intellectual premise for colonization – its civilizing mission. Early British scholars documented Indian thought and its external manifestations as systems competing with their own and thus facilitated the transfer of technology into what became known as Britain's Industrial Revolution. What was found valuable was quickly appropriated and its Indian manufacturers were forced out of business, often through draconian laws enacted by the British. This was, in many instances, justified as civilizing them. Meanwhile, a new history of India was fabricated to ensure that generations of mentally colonized people would believe in the inherent inferiority of their own traditional knowledge. This has been called Macaulayism, named after Thomas Macaulay, the civil servant who became the most prominent champion of such British cultural imperialism strategy starting in the 1830s.

When it became difficult for Europeans to ignore the massive archaeological evidence of classical Indian science and technology, they asserted that the Indus-Sarasvati Civilization had to be a transplant from the Egyptian and Mesopotamian civilizations. These constructions in historiography have been cumulative rather than re-constructive: more theoretical layers are constructed to explain new contradictory data rather than prior ones being re-examined or corrected. Unfortunately, despite Indian independence there has not been much effort at correcting these distortions. Many among India's intellectual elite continue to promote the notion that pre-colonial India was feudalistic, pre-rational, and, by implication, in need of being invaded for its own benefit.

This has created a climate in which entrenched prejudice against non-Western knowledge persists. Even after independence, an institutional bias against traditional technologies continues.

It is important to note that among all the conquered and colonized civilizations of the Old World, India is unique in the following respect: its wealth was industrial and created by its workers' ingenuity and labor. In the case of the Native Americans, the plunder by the colonizers was mainly of land, gold and other natural assets. In the case of the Africans, the plunder was both of natural assets and of slave labor. But in India's case, the colonizers had a windfall – extraordinary profit margins from the control of India's exports, the taxation of its economic production, and eventually the transfer of its technology and production to the colonizer's home.

This comprised an immense transfer of wealth out of India to Europe. From being the world's major exporting economy (along with China), India was reduced to an importer of goods; from being the source of much of the economic capital that funded Britain's Industrial Revolution, it became one of the biggest debtor nations; from its envied status as one of the wealthiest nations, it became a land synonymous with poverty; and from a nation with a large number of prestigious centers of higher education that attracted the cream of foreign students from Asia, it became the land with the highest number of illiterate persons. This remains a major untold story. The West has failed to recognize that its position of power was gained not by its inherent superiority but by the fact that it was successful in trampling over others.

The justification for this gross exploitation and denigration of colonial victims was known as the civilizing mission. The colonial powers argued that in exchange for the wealth they plundered, both material and intellectual, they were providing the colonized people an opportunity to 'modernize'. But, first, they had to create the perception that the West held all the keys to progress and that it was benevolently willing to share its gifts with the world. This perception was manufactured by Eurocentric historiographies and the manipulation, distortion, and concealing of historical data. In the Indian context, colonial Indologists were required to create a portrayal of India as a region that was backward and in need of colonial stewardship.

After independence, many Indian intellectuals continued to use the pre-colonial, feudalistic framework of Indian society. In contrast, Arab scholars have brought out the important role of Islamic empires in the transmission of ideas into Europe. However, many discoveries and innovations of India, as acknowledged by the Arab translators themselves, are now often depicted as being of Arab origin, when in fact, the Arabs often retransmitted what they had learnt from India over to Europe.

In the case of China, Joseph Needham, a leading scholar at Cambridge, made it his life's work to document China's history of science and technology in over 30 volumes. By the time he died at age 90, his works had transformed the study of China forever. The Needham Foundation has continued this monumental work, and has been expanding the series with new volumes. Today, every research library on China, and every major library on science and history, has the Needham collection as important reference. Every serious China scholar respects this work, and its impact on the perception of China has been phenomenal. This impact has also trickled down to depictions in schools and the general media.

Unfortunately, India is yet to achieve this kind of intellectual repositioning. It continues to be depicted through "caste, cows and curry" images all too often. Indian culture is frequently portrayed as being mystical in the sense of being irrational, and in lacking a sense of advancement in the material plane of society. Often, many Westernized Indians internalize these colonial stereotypes. Amartya Sen expressed his views on this as follows:

> *"Fear of elitism did not, happily, deter Joseph Needham from writing his authoritative account of the history of science and technology in China, and to dismiss that work as elitist history would be a serious neglect of China's past…*
>
> *"A similar history of India's science and technology has not yet been attempted, though many of the elements have been well discussed in particular studies. The absence of a general study like Needham's is influenced by an attitudinal dichotomy. On the one hand, those who take a rather spiritual – even perhaps a religious – view of India's history do not have a great interest in the analytical and scientific parts of India's past, except to use it as a piece of propaganda about India's greatness (as in the bloated account of what is imaginatively called 'Vedic mathematics', missing the really creative period in Indian*

mathematics by many centuries). On the other hand, many who oppose religious and communal politics are particularly suspicious of what may even look like a 'glorification' of India's past. The need for a work like Needham's has remained unmet (Sen, 1997: 32)."

To elaborate on the colonial destruction of Indian industry, a subsequent chapter, *"Colonial Destruction of India's Textile Industry"*, gives a detailed account of a major instance of this colonial sabotage. We leave it to the reader to infer the fate of India's other major industries.

<u>Reason 3:</u> To compete globally, Indians must de-colonize their minds:

Facts contradict the following common stereotypes:

- India was less rational and scientific than the West.
- India was world negating in its outlook, frozen in time and unable to advance without help from foreign invaders.
- India's civilization was mainly imported via invaders, except for its problems such as caste that were its own 'essences'.
- Indian society was socially backward (to the point of being seen as lacking in morality), hence dependent upon Westernization to reform its current problems.

This should lead to the following introspection: Is India a 'developing' society, or is it a 'redeveloping' society? Were Indians always poor, always living in polluted and socially problematic conditions, and are these problems Indian essences? Or is there a history behind its present sociopolitical adversities? This history should not, however, excuse the failures of 50 years of independence to deal with the economic and social problems that persist.

Indians need to overhaul their own assessment of their potential. Is India meant to be a nation dependent on importing technology and intellectual property, as we have been told for so long? Or is India meant to be a nation of exporters of technology and intellectual property, as Infinity Foundation believes?

The implications are staggering. The choices are dramatic and opposite:

- Should India upgrade its higher education in order to compete globally as an intellectual place of learning, competing with the West's best universities for the multi-billion dollar education industry? This would be a return to India's role in classical times, when its *vihara*s (intellectual hubs) such as Nalanda and Taxashila attracted the cream of Asia's scholars much like Ivy League institutions in the United States do now.
- Or should India continue to depend on Western higher education for its paradigms, frameworks, research and development, certification of competence and credibility, careers and legitimacy for its brightest youth?

China has embarked on a massive upgrade of its universities in order to export higher education to the third world. Its strategy is not driven by short-term economic income but by

a long-term ambition to counter the West by spreading its own influence to the next generation of thinkers worldwide. These bold moves cannot come out of inferiority complexes, such as those that plague many educated Indians today.

Until the 1800s, traditional knowledge generated large-scale economic productivity for Indians. It was the thriving Indian economy that attracted so many waves of invaders, culminating with the British. Traditionally, India was one of the richest regions in the world, and most Indians were neither 'backward' nor uneducated or poor. Some historians have recently begun to demonstrate that it was economic drainage, oppression, social re-engineering at the hands of colonizers that made millions of 'new poor' over the past few centuries. This explanation yields a radically different reading of the poverty in India today. Upon acknowledging India's traditional knowledge systems, one is forced to discard accounts of its history that essentialize its poverty and related social evils.

Contemporary India's outsourcing industries and its ability to attract investments also depend on unstated, and often unconscious, impressions about India as a place to do business and about Indian culture. Since India sees itself as a global power, or at least a regional power, it must also embark on intellectually repositioning its brand – away from being seen as the center of human rights abuses, naked *sadhu*s, exotica and erotica. There is no better place to start than via its long track record in science and technology.

It is often said that Indians' recent excellent performance in the global economy – as medical doctors, information technologists, financial experts, corporate managers – must be the positive effect of colonialism. One hears even Indians internalize explanations of their success as being the result of colonizers teaching them "rational thought", English, democracy, and so forth. An honest account of the history of ideas would make such Western chauvinism untenable. For example, one might raise the following objections:

1 Prof Fritz Staal, a well known Indologist, explains the relevance of Indian thought in today's leading-edge research areas in an article titled, *"Artificial Intelligence: Asian backgrounds or influences."* (See: http://www.iias.nl/iiasn/30/IIASNL30_15.pdf)

2 If learning the colonizer's language and customs were the cause for Indians becoming scientific minded, then why are most African, Latin American and many other third world former European colonies not able to develop as fast as India has done? The fact is China's and India's development should be seen not as development but as re-development, meaning that these civilizations' very fabrics have a culture of advancement through rational thought for millennia, and they are now reviving their innate capabilities that had become dormant and/or suppressed.

3 Al-Beruni and other visitors recorded centuries ago that Indians were among the leading medical practitioners, researchers and educators in the Middle East. Records in China support these claims. Indians pioneered in various fields of mathematics, metallurgy, agriculture, medicine, shipping and trade, language. India was the mother of pan-Asian

civilizations in certain ways just as Greece was the mother of European civilization. This Indian influence on East and Southeast Asia is acknowledged by those societies today and is well-documented in their own writings, but not in the writings by European writers where Indian sources are often marginalized.

Indian Americans have additional factors to consider. Every new immigrant group in the US has had to define itself in the eyes of the American public though a process of education about its history, culture, values and special strengths. Americans are a very open-minded and fair people in judging newcomers, but the burden is on the newcomers to self-represent. This is not something one may reasonably abandon to others to do on one's behalf. The Indian American identity is now being negotiated in the US and Indians must be proactive.

Section II: Indian Contributions to Science and Technology

The depth and breadth of Indian science and technology is staggering, and this section gives just a glimpse into the genius of India's scientists and engineers.

Civil Engineering:

From complex Harappan towns to Delhi's Qutub Minar, India's indigenous technologies were very sophisticated. They included the design and planning of water supply, traffic flow, natural air conditioning, complex stone work, and construction engineering.

Most students learn about the ancient cities of the Middle East and China. How many have even a basic understanding of the world's oldest and most advanced civilization – the Harappan or Indus-Sarasvati Valley Civilization in India? The Indus-Sarasvati Civilization was the world's first to build planned towns with underground drainage, civil sanitation n, hydraulic engineering, and air-cooling architecture. While the other ancient civilizations of the world were small towns with one central complex, this civilization had the distinction of being spread across many towns, covering a region about half the size of Europe. Weights and linguistic symbols were standardized across this vast geography, for a period of over 1,000 years, from around 3,000 BCE to 1500 BCE. Oven-baked bricks were invented in India in approximately 4,000 BCE. Over 900 of the 1,500 known settlement sites discovered so far are in India.

Since the Indus-Sarasvati script is yet to be decoded, it remains a mystery as to how these people could have achieved such high levels of sophistication and uniformity in a dispersed complex and with no visible signs of centralized power.

For instance, all bricks in this civilization are of the ratio 1:2:4 regardless of their size, location or period of construction. There are many pioneering items of civil engineering, such as drainage systems for water (open and closed), irrigation systems, river dams, water storage tanks carved out of rock, moats, middle-class style homes with private bathrooms and drainage, and even a dockyard; there is evidence of stairs for multiple-storied buildings;

many towns have separate citadels, upper and lower towns, and fortified sections; there are separate worker quarters near copper furnaces; granaries have ducts and platforms; and archeologists have found geometric compasses, linear scales made of ivory. Indians also pioneered many engineering tools for construction, surgery, warfare, etc. These included the hollow drill, the true saw, and the needle with the hole on its pointed end. (For further details, see the book summaries in later chapters.)

Water Management:

Given the importance of fresh water in India, it is no surprise that the technologies to manage water resources were highly advanced from Harappan times onwards. For example, in Gujarat, Chandragupta built the Sudarshan Lake in late 4th century BCE, and was later repaired in 150 BCE by his grandson. Bhopal's Raja Bhoj Lake, built in 1014-1053, is so massive that it shows up in satellite images. The Vijayanagar Empire built such a large lake in 14th – 15th century CE that it has more construction material than the Great Wall of China. What some historians call the "Persian Wheel" is actually pre-Mughal and indigenous to India.

Scientists estimate there were 1.3 million man-made water lakes and ponds across India, some as large as 250 square miles. These are now being rediscovered using satellite imagery. These enabled rain water to be harvested and used for irrigation, drinking, etc. till the following year's rainfall.

Textiles:

Indian textiles have been legendary since ancient times. The Greeks and Romans extensively imported textiles from India. Roman archives record official complaints about massive cash drainage due to these imports from India.

One of the earliest industries relocated from India to Britain was textiles and it became the first major success of the Industrial Revolution, with Britain replacing India as the world's leading textile exporter. What is suppressed in the discourse about India and Europe is the fact that the technology, designs and even raw cotton were initially imported from India while, in parallel, India's indigenous textile mills were outlawed by the British. India's textile manufacturers were de-licensed, even tortured in some cases, over-taxed and regulated, to 'civilize' them into virtual extinction. Textiles and steel were the mainstays of the British Industrial Revolution. Both had their origins in India. The Ahmedabad textile museum is a great resource for scholarly material.

Iron and Steel:

Iron is found in countries neighboring India, leading European scholars to assume that it came from outside India. Given the similarities between the Vedas and Avesta (a Zoroastrian text), some saw this as supporting the theory of diffusion of iron and Vedas into India from

the outside. Refuting this, Vibha Tripathi finds that iron in India is much older. (See details in a subsequent chapter.) Cemeteries in present-day Baluchistan have iron objects. The earlier iron found in Middle Eastern archeological sites was essentially meteorite material sculptured as rock/stone carvings, and was not metallurgically processed at all. Since iron can be a by-product of copper technology, this could be its likely origin in India because copper was a well-known technology in many parts of ancient India. A smelting furnace dated 800 BCE is found in Naikund (Maharashtra), India. Recent discoveries reveal that iron was known in the Ganga valley in mid second millennium BCE. In the mid-first millennium BCE, the Indian wootz steel was very popular in Persian courts for making swords.

Rust-free steel was an Indian invention, and remained an Indian skill for centuries. Delhi's famous iron pillar, dated 402 CE, is considered a metallurgical marvel and shows minimal signs of rust. The famous Damascus steel swords, now displayed in museums across Europe, were made from Indian steel imported by Europeans. The acclaimed Sheffield steel in UK was Indian crucible steel. The best brains of European science worked for decades to learn to reverse-engineer how Indians made crucible steel, and in this process, modern alloy design and physical metallurgy was developed in Europe. (For details see later chapters with book summaries.)

Indian industry was dealt a death blow by the colonial masters who banned the production and manufacture of iron and steel at several places in India, fearing their use in making swords and other arms. In addition, they also ensured India would depend upon iron and steel imported from Europe.

Zinc Metallurgy:

Another important Indian contribution to metallurgy was in the isolation, distillation and use of zinc. From natural sources, zinc content in alloys such as brass can go no higher than 28 per cent. These primitive alloys with less than 28 per cent zinc were prevalent in many parts of the world before India. However, to increase the zinc content beyond this threshold, one must first separate the zinc into 100 per cent pure form and then mix the pure zinc back into an alloy. A major breakthrough in the history of metallurgy was India's discovery of zinc distillation whereby the metal was vaporized and then condensed back into pure metal.

Brass in Taxashila has been dated from third century BCE to fifth century CE. A vase from Taxashila is of particular interest because of its 34.34 per cent zinc content and has been dated to the third century BCE (Marshall 1951: 567-568). Recently two brass bangles belonging to the Kushana period have been discovered from Senuwar (Uttar Pradesh, India). They are also made of metallic zinc as they have 35 per cent zinc content (Singh 2004: 594). Experts are unsure if this zinc was made by distillation process.

There is evidence of zinc ore mining at Zawar in Rajasthan from the fifth century BCE, but

unfortunately there is lack of evidence of regular production of metallic zinc until the eighth century CE. The earliest confirmed evidence of zinc smelting by distillation is dated back to 840 $\pm$110 from Zawar (Craddock *et al.* 1985, 1989). This is the earliest date for zinc smelting and production of metallic zinc by distillation process anywhere in the world.

Europeans learnt it for the first time in 1743, when know-how was transferred from India. Until then, India had been exporting pure zinc for centuries on an industrial scale. At archeological sites in Rajasthan, retorts used for the distillation are found in very large numbers even today.

Once zinc had become separated into a pure metal, alloys could be made with the required zinc component to provide the required properties. For instance, strength and durability increase with higher zinc component. Also, copper alloys look like gold when the zinc component is higher than 28 per cent. Most early brass objects found in other countries had less than 10 per cent zinc component, and, therefore, these were not based on zinc distillation technology.

Alloys that exceed 10 per cent zinc are found earliest in Taxashila in the fourth century BCE. However, while Taxashila was distilling and manufacturing zinc on a small scale, it was in Zawar, Rajasthan, where this first became industrialized on a large scale. Zinc mines have been found in Dariba (11th century BCE), Agucha (sixth century BCE) and Zawar (fifth century BCE). These mines have pots and other manufacturing tools of these dates, but the mining could be even older. (See further details in later chapters.)

Three important items are now proven about the history of zinc metallurgy: (i) zinc distillation and metallurgical usage was pioneered in India; (ii) industrial scale production was pioneered in Rajasthan; (iii) England transferred the technology of zinc from India in 1736. British metallurgy documents do not mention zinc at all prior to this transfer.

Shipping and Shipbuilding:

Shipbuilding was one of India's major export industries until the British dismantled it and formally banned it. Medieval Arab sailors purchased their boats in India. The Portuguese also continued to get their boats from India and not Europe. Some of the world's largest and most sophisticated ships were built in India and China.

The compass and other navigation tools were already in use in the Indian Ocean long before Europe. ("*Nav*" is the Sanskrit word for boat, and is the root word in "navigation" and "navy".) Using their expertise in the science of seafaring, Indians participated in the earliest-known ocean-based trading system.

Few people know that an Indian naval pilot, named Kanha, was hired by Vasco da Gama to captain his ships and take him to India. Some of Europe's acclaimed "discoveries" in

navigation were in fact appropriations of a well-established thriving trade system in the Indian Ocean. Contrary to European portrayals that Indians knew only coastal navigation, deep-sea shipping had existed in India as Indian ships had been sailing to islands such as the Andamans, Lakshdweep and Maldives around 2,000 years ago. Kautilya describes the times that are good and bad for seafaring. There is also extensive archival material on the Indian Ocean trade in Greek, Roman, and Southeast Asian sources.

Forest Management:

Many interesting findings have recently come out about the way forests and trees were managed by each village and how a careful method was applied to harvest medicines, firewood and building material in accordance with natural renewal rates. There is now a database being built of 'sacred groves' across India. Once again, it's a story of an economic asset falling into disuse and abuse because of the dismantling of local governance and disrespect for traditional systems.

Furthermore, when scholars try to explain India's current ecological disasters, they seldom mention the large-scale logging of Indian timber by the British in order to fund the two world wars and various other industrial programs of the empire.

Farming Techniques:

Indian farmers developed non-chemical, eco-friendly pesticides and fertilizers that have modern applications. These traditional pesticides have been recently revived in India with excellent results, replacing Union Carbide's products in certain markets. Crop rotation and soil technology that has been passed down for thousands of years are traditional practices which India pioneered.

Historically, India's agricultural production was large and sustained a huge population compared to other parts of the world. Surpluses were stored for use in a drought year. But the British turned this industry into a cash cow, exporting very large amounts of grain even during food shortages. This caused tens of millions of Indians to die of starvation in the 19th century.

Traditional Medicine:

Much re-legitimizing of traditional Indian medicine has already started, thanks in part to many Western labs and scientists. Many multinationals no longer denigrate traditional medicine and have in fact been trying to secure patents on Indian medicine without acknowledging the source. Traditional medicine is now a well-known and respected field.

Mathematics:

Prof. C.K Raju, a renowned scholar, has researched the “clash of epistemologies” that

occurred in European ideas about numbers. When Europeans started to import Indian ideas about mathematics, what had been natural to Indian thinkers for a long time was very hard for Europeans to accept. He divides this into three periods:

1 The first math war in Europe was from 10th to 16th centuries, during which time it took Europe 500 years to accept the zero, because the Church considered it to be heresy.

2 The second math war was over the Indian concept of indivisibles, which led to the theory of real numbers and infinitesimals, paving the way for the development of calculus. This war lasted three centuries, from the 17th to 19th centuries.

3 The third math war is now under way and is between computational math (Indian algorithmic approach) and formal math (Western approach).

Additionally, Indians developed many important concepts including the base-ten decimal system, now in global use, and crucial trigonometry and algebra formulae. They made several astronomical discoveries. Diverse schools of logic and philosophy proliferated.

Mathematical thought was intertwined with linguistics. India's Panini is acknowledged as the founder of linguistics, and his Sanskrit grammar is still the most complete and sophisticated of any language in the world.

“Folk” Sciences:

Besides the above examples of Indian contributions to the origins of the so-called “Western” science, there is another category of traditional knowledge called non-literate folk science. Western science as a whole has condemned and ignored anything that it did not either appropriate or develop, by branding it as magic and superstition. However, in countries such as India, which boast of cultural continuity, ancient traditions survive with a rich legacy of folk science.

In North America and Australia, where original populations have been largely decimated, such continuity of folk tradition was disrupted. In Western nations with large colonies in the Old and New Worlds, such knowledge systems were looked down upon once they had been successfully plundered. The process of contrasting Western science with folk knowledge systems has led to the imposition of contrived hegemonic categories.

The distinction between elite and folk science was non-existent in ancient times. India's advanced metallurgy and civil engineering was researched and practiced by artisan guilds. Western science seldom realized that non-literate folk science preserves the wisdom gained through millennia of experience and direct observation, and has been transmitted by word of mouth.

For instance, modern scientists have humbly admitted that the ecological management

practiced today by the tribes of India's Northeast is far superior to anything they could teach them. A good example is the use of alder (Alnus nepalensis), which has been cultivated in the *jhum* (shifting cultivation) fields by the Khonoma farmers in Nagaland for centuries. It has multiple usages for the farmers, since it is a nitrogen-fixing tree and helps to retain the soil fertility. Its leaves are used as fodder and fertilizer, and it is also utilized as timber. One could cite numerous such examples.

The vast majority of modern medicines patented by Western pharmaceutical firms are based on tropical plants. The most common method to select candidates for detailed testing has been for Western firms to scout tropical societies, seek out established "folk" remedies and subject these to testing by "Western science". In many cases, patents owned by multinationals are largely for isolating the active ingredients in a lab and going through rigorous protocols of testing and patent filing. While this is an important and expensive task that deserves credit, these are seldom truly independent discoveries from scratch. Never has the society that has discovered them through centuries of empirical trial and error received any recognition, much less any share of royalty.

Colin Scott writes: *"With the upsurge of multidisciplinary interest in 'traditional ecological knowledge', models explicitly held by indigenous people in areas as diverse as forestry, fisheries, and physical geography are being paid increasing attention by Western scientists, who have in some cases established extremely productive long-term dialogues with local experts. The idea that local experts are often better informed than their Western peers is at last receiving significant acknowledgment beyond the boundaries of anthropology."*

Myths and legends sometimes represent the attempts of our ancestors to explain the scientific observations they made about the world around them and transmitted these to the future. They chose different models to interpret the observations, but the observations were empirical. Theorizing the possible role of myths, Scott writes: *"The complementarity of the literal and the figurative helps us to realize that the distinction between myth and science is not structural, but procedural ... Myths in a broader, paradigmatic sense are condensed expressions of root metaphors that reflect the genius of particular knowledge traditions ... Numerous studies have found that the "anthropomorphic" paradigms of egalitarian hunters and horticulturalists not only generate practical knowledge consistent with the insights of scientific ecology, but simultaneously cultivate an ethic of environmental responsibility that for western societies has proven elusive."*

Despite these acknowledgments, in too many cases Western scholars reduce India's experts to "native informants" who are seen located below the glass ceiling: the pandit as native informant to the Western Sanskritist; the poor woman in Rajasthan as native informant to the Western feminist seeking to cure her of her native tradition; the herbal farmer as native informant to the Western pharmaceutical firm appropriating medicines for patents. Given their poverty in modern times, these 'native informants' dish out whatever the Western scholar expects to hear in order to fit his/her thesis, because in return they receive rewards.

Rarely have Western scholars acknowledged India's knowledge bearers as equal partners. The obsession to make 'original' discoveries and to put one's name on publications has exacerbated the tendency to appropriate with one hand, while denigrating the source with other hand. This deserves to be called 'academic arson'.

Relationship with Inner Sciences:

India's inner sciences of mind and consciousness are simultaneously (a) being appropriated by the West and (b) being depicted as anti-progressive and irrational. In fact, inner and outer realms of inquiry are often viewed as opposites that can, at best, be balanced but not unified. This falsely assumes that the inner sciences make a person and society less productive, creative, and competitive in the outer realm. However, contradicting this, India's inner sciences and outer development coexisted in a mutually symbiotic relationship.

A strong inner science will definitely strengthen the outer science since it is the inner world which provides the inspiration, creativity, and knowledge that is necessary in the development of a sound outer science. A strong outer science allows the freedom for the exploration of the inner science. Without the use of technology of some form, man will be forced to dwell in his lower nature to satisfy his basic needs of survival.

The divorce of 'religion' and science is a strictly Western construct due to the dogmatic and rigid nature of the Abrahamic religions. History-centric religions (such as Judaism, Christianity, and Islam) are often not compatible with the human tendency towards freedom of thought, intellectual originality, and non-conformity of thought which are necessary in scientific innovation. The tradition of spiritual experimentation in India, however, is compatible with the material and intellectual experimentation required by science.

Section III: Infinity's Book Series on *History of Indian Science & Technology*

An exploration free from the phobias against Indian Civilization would show that the West did not come out on top due to any inherent superiority, as claimed by Hegel and others, but, rather, due to their cunning and ruthlessness. This kind of research will establish that non-Western minds not only have the ability to contribute to original technology, but, in fact, have been instrumental in its development. India's own English-educated elite should be made aware of these facts to shed its Macaulayite complexes.

Since colonial Indology and world history have become institutionalized over many decades, many of the reference works and popularly used texts are in drastic need of being rewritten. The availability of new reference works for scholars would alter the historical assessment of India. However, it is obvious that the current institutions controlling the intellectual discourse do not desire to alter the power equation.

Therefore, the Infinity Foundation has stepped up to meet this challenge. There is extensive

documentation of Indian contributions to the world in science and technology, but this is largely scattered and disorganized. The purpose of Infinity's project is to amalgamate this mass of information into one definitive book series, just as Prof. Needham did for China.

Each proposed volume is estimated to be completed in three years from the time of commission. Each volume has its own schedule and timetable, depending on the particular subject. Some volumes require more original research, even field data gathering, while others are mainly a matter of library research – to identify, compile and validate pre-existing academic works, categorizing them according to modern standards.

Volumes commissioned already:

#	Title	Author(s)
1	Marvels of Indian Iron Through the Ages	R. Balasubramaniam
2	Harappan Architecture and Civil Engineering	J.P. Joshi
3	Harappan Technology & Its Legacy	D.P. Agrawal
4	Himalayan Domestic Architecture	O.C. Handa
5	Channeling Nature: Hydraulics, Traditional Knowledge Systems, And Water Resource Management in India - A Historical Perspective	Rima Hooja
6	Ancient Indian Iron Technology Vol. 2	Vibha Tripathi
7	Textures of 'Wootz'	Sharada Srinivasan
8	Zinc Production in Ancient India	J.S. Kharakwal
9	Chalcolithic Technology	V. Shinde, S.S. Deshpande

Anticipated future volumes:

1 Traditional Architecture and Hydraulics in the Himalayan Region
2 Ancient Ship Building and Navigation
3 Early Glass Technology and Gemstones
4 History of Ancient Indian Mathematics
5 Transmission of Indian influences into Modern European Mathematics
6 Science and Technology in early India (1000 BCE-500 CE)
7 Archaometallurgy of Eastern India
8 Civil, Military, Hydraulic, and Marine Engineering in Early Historical Periods
9 Early Animal Husbandry
10 History of Ceramic Technology
11 History of Textile Technology
12 South Indian Water Tank Technology
13 Traditional Indian Martial Arts

Besides the above list, Infinity Foundation welcomes new proposals.

What makes this project different?

There are many important ways in which this project differs from others that might appear to be similar:

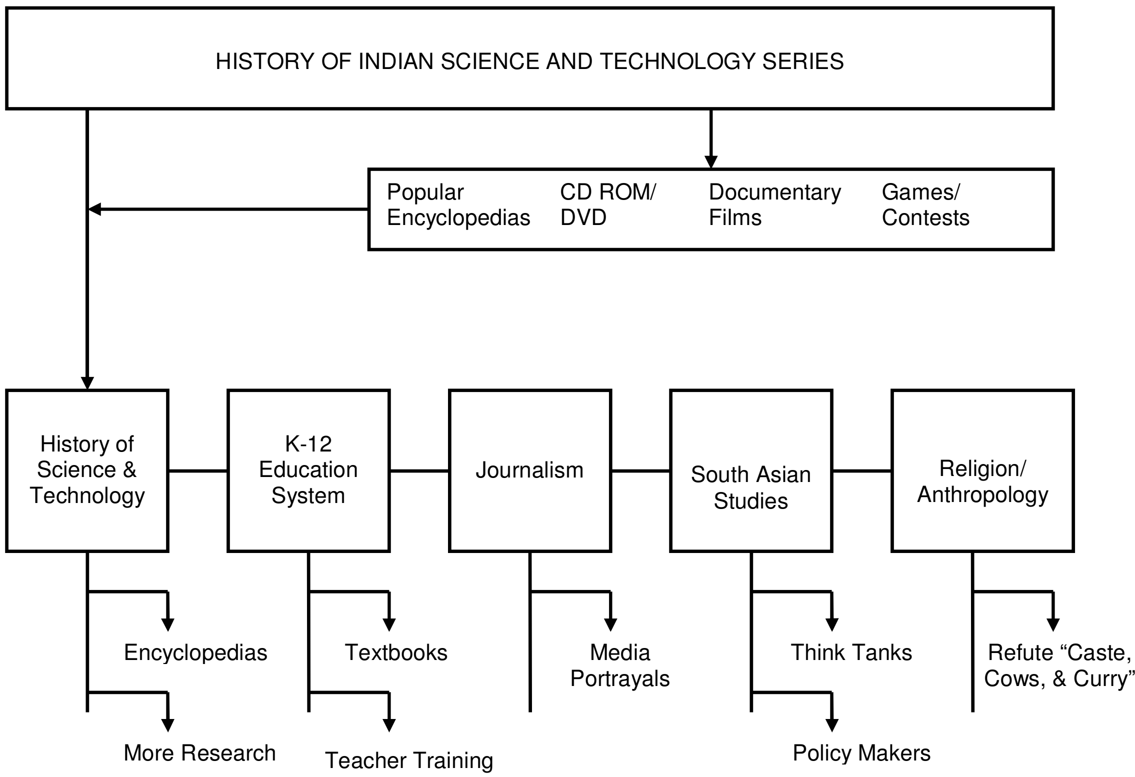
1. The government of India started a multi-volume project many years ago, but it has focused mainly on philosophy and not on practical science or technology. Furthermore, being government-driven, it is not market-oriented in its packaging or distribution. It is seldom referenced by textbook authors and is rarely found in libraries.

2. Some writers have tended to exaggerate claims of Indian scientific accomplishments by wildly interpreting statements written in classical texts. Based on such textual references for which there is no physical evidence, they have concluded that there was space travel in the Mahabharata, along with nuclear weapons and just about every modern hi-tech item. This has justifiably earned them the term “chauvinists,” and the entire activity of writing about Indian science has become discredited. Infinity Foundation considers it very important to distance itself from such discredited scholarship. This is why our book series is being built on solid academic scholarship only, and not on lofty extrapolations. Researching unsubstantiated claims about old knowledge does have its place, but facts must be separated from unproven hypotheses. Therefore, this project does not include *Puranas* as scientific sources. Our project involves rigorous peer reviews of each manuscript.

3. Many other works do not make much impact because of poor distribution. Often scholars seem unconcerned about marketing aspects, because it is only important for them to claim the academic achievement on their resumes. Infinity Foundation is planning widespread distribution of its works because the project’s success depends on actual usage in the academic mainstream and not simply on decorating a few research libraries. To achieve this impact, Infinity Foundation has studied the process of dissemination of knowledge in mainstream school curricula, college courses, and mass media. This is documented in the diagram that follows. Infinity Foundation is expecting to sponsor the following as part of this mission:
    a. Teacher training workshops on the use of these books
    b. Academic seminars to popularize them among scholars
    c. Games and contests in science and general knowledge based on the books
    d. Inexpensive editions that could be donated to libraries in developing societies.
    e. Documentaries based on the books.
    f. Eventually CD-ROM/DVD with pictures and music.

4. There must be new editions every few years to keep the volumes current and expanding. To achieve this, the project would like to become financially self-sufficient so that revenues are used to continue the work indefinitely. New titles, regular conferences and other activities should keep this series fresh in the minds of

educators.



Responding to Critics and Cynics:

Some critics have claimed that this series is anti-Western. Our response is that it is in everyone's best interest to have a truly global education system in which all cultures' contributions and merits are celebrated. This necessitates demolishing false notions of history promulgated by the colonizers.

Others who are deeply brainwashed in India phobia may find it convenient to dismiss this book series as "Hindutva", "right-wing fundamentalist", and so forth. This is completely baseless since Indian science is not about any particular religion. It is the heritage of every Indian, regardless of faith or lack thereof. Just as Newtonian laws are not Christian and Einstein's relativity theory is not a Jewish science, so also the scientific discoveries of Indians are independent of their faiths.

The importance of this work may be compared to Europe's use of classical Greek thought to raise itself out of the Dark Ages. India should also look to its own rich tradition of knowledge to move forward and complement modern knowledge.

Ch2

HIGHLIGHTS OF HARAPPAN TECHNOLOGY

D P Agrawal

Contents:

1. Introducing the Harappans
2. Agriculture
3. Transport
4. Stone technology
5. Ceramic Technology
6. Metal Technology
7. Standardization
8. Architecture
9. Hydraulics
10. Innovations
11. Legacy
12. Bibliography

1. INTRODUCING THE HARAPPANS

The most widely published culture of ancient India is the Harappan Culture: there are several excellent books on it. But I think that a well integrated account of the Harappan technology, covering its myriad facets, is still not there. The innovations made during that period in the fields of architecture, town planning, metallurgy, agriculture, hydraulics, transport, and ceramic technology, in their totality make a tantalising impact. A detailed exposition of the Harappan technology also helps correcting the Eurocentric distortions, as the Indus Civilisation was one of the oldest civilisations of the world with so many innovations to its credit.

Their cultural and technological traits also give a glimpse of the formative phase of the Indian Civilisation, as it is the Harappa Culture which provides the basic substratum to the former. The legacy left by the Harappans is so all-pervasive in the Indian culture that even simple things of life that we are used to (like *sindoor* on the *maang*, toiletries etc.) have to be traced back to 5000 years, to their Harappan roots.

In this brief overview, I am trying to present a multifaceted, yet holistic, picture of the Harappan science and technology. In its technological virtuosity, it stands tall and unique in the Third Millennium BCE world.

The Indus Civilization, though archaeologists prefer to call it the Harappa culture (named after the first discovered site, Harappa), is remarkable for its uniformity and standardization in

weights, measures, ceramics, architecture, town planning and in other arts and crafts. This uniformity appears all the more imposing when one considers that the culture extended over an area covering more than that of the present-day Pakistan. Recent studies, however, are also bringing out a good deal of regional variation.

The Harappa culture was spread over close to two million sq km area (JP Joshi in press). In the west Sutkagendor (Makran), in the east Alamgirpur (UP), Ropar in the north, and Bhagatrav in South Gujarat represent the outer limits of culture, though the culture is mainly confined to the Indus Valley and Saurashtra, including Kachchha (Fig. 1, map).

Wheeler tried to define the Harappa culture by the alternative or accumulative presence of: (i) Indus seals; (ii) Indus script; (iii) motifs like intersecting circles; (iv) ceramic forms like goblets with pointed base, cylindrical pots with multiple perforations, jars with S-profile and dishes-on-stand; (v) triangular terracotta cakes; (vi) kidney-shaped inlays of shell or faience; and (vii) certain beads, notably discoid with tubular holes. To these characteristics one may add town-planning (streets in grids, underground drains, and fortified townships); brick dimensions in the ratio of 1:2:4; and typical shapes of copper artefacts like bent-bladed knives, double-edged razors, barbed triangular arrowheads with holes etc.

There are frequent and consistent references in the Mesopotamian texts to Dilmun and Magan (Makkan) with which the Harappans had frequent commercial intercourse. And all these places could be approached by boat. There is now a consensus to identify Dilmun with the Turant, Bahrain and Kuwait region. Magan has been identified with Umm-an-Nar near Abu Dhabi. Meluhha generally represents the Harappan zone.

As far as religion is concerned, most of the elements of the latter-day Hindu god Siva were already there in the Harappa culture. In one of the seals a deity is shown with a supplicating figure with a sacrificial goat. Concern for personal cleanliness, bath and ablution is traditional in India. The Great Bath of Mohenjodaro may be the beginning of these ablutionary rituals (Figs. 5, 6). The normal Harappan burial custom was inhumation in unlined pits, head pointing north.

Asko Parpola, Konorozov, and others favour a Dravidian affinity of the Indus script, whereas Rao and some others claim it to be an Indo-Aryan language.

Kenoyer has given the following chronology about which there is considerable consensus.

Table 1. General Dates And Archaeological Periods

EARLY FOOD PRODUCING ERA	c. 6500 to 5000 BCE
Aceramic Neolithic	
REGIONALIZATION ERA	c. 5000 to 2600 BCE

Early Harappan
Early Chalcolithic
Ceramic Neolithic

Integration Era c. 2600 to 1900 BCE
Mature Harappan
Chalcolithic/Bronze Age

Localization Era c. 1900 to 1300 BCE
Late Harappan

We summarise below the Harappan technology under the following categories: Agriculture; Transport; Stone technology; Ceramic technology; Metal technology; Standardization; Architecture; Hydraulics; and Innovations.

2. AGRICULTURE

The first agricultural revolution took place in the sixth millennium BCE based principally on the *rabi* crops (winter sown, spring harvested) of wheat and barley and on certain domestic bovid~~s~~ including zebu cattle, sheep, and goats. The second saw the addition, during the early second millennium BCE, of *kharif* cereals (summer sown, fall harvested) including sorghum, various millets, and rice along with new domestic animals including the camel, horse, and donkey.

From the Pre-Harappan period at Kalibangan: a field, with furrows running at right angles to each other, in north-south and east-west directions was found. The distance between the two north-south running furrows was 1.9 m and between the east-west running furrows was 30 cm. It is interesting to note that even today mustard (in wider furrows) and horse gram (in narrow furrows,) is simultaneously grown in that area. It is quite probable that this practice was adopted by the Harappans also in Rajasthan. By sowing the mustard plants in the north-south rows care is taken that their shadows fall more on one another rather than on the horse gram plants. Had the mustard plants been sown in the east-west rows, their shadows would have completely covered the horse gram plants, depriving the latter of the sun's rays and consequently hampering their growth.

Wooden ploughs, with perhaps a sharp-ended copper bar attached to its end, seem to have been used for tilling fields. Both Mohenjodaro and Banawali have yielded a terracotta plough models. The presence of a large number of chert blades, retaining the gloss on the cutting edge, indicates that these were used for harvesting. Indeed stone blades set with bitumen in wooden handles have been found in much earlier levels at Mehrgarh. These also bear the sheen.

The Harappans also had the knowledge of grapevine cultivation. Hyacinth-bean (*Lablab purpureus*) from Mahorana is an unequivocal vegetable cultivation. One may presume that the ladies might ~~be~~ have been using henna for embellishment. The evidence of *parijata*

(*Nyctanthes arbortristris*) in the charcoal remains at the same site is an ornamental plant with fragrant flowers. Cultivation of ornamental plants for fragrant flowers is further evidenced by jasmine (*Jasminum* sp.) charcoal from a recently excavated site at Sanghol in Ludhina District.

About the Harappan agriculture, Weber and Belcher draw some important conclusions:

1. There appears to have been a constant and gradual process of increasing use of summer cropped plants, with the biggest jump seen in the Late Harappan samples. It is in this Late Period where we see the summer-cropped seed density and ubiquity at its highest and most significant levels relative to the winter-cropped plants.

2. There is also a constant increase in the number of different species being cultivated at Harappa. With few crops ever disappearing from the diet, each period sees a significant increase in crop diversity from the previous period. These plants, whether local varieties or species being introduced from great distances away, appeared as part of a gradual process of supplementing existing crops. At the earliest occupation, barley is the dominant grain. During the Harappan Period, wheat increases in ubiquity, density, and percentage until it becomes the most common species at Harappa.

About 80 per cent of the faunal assemblage from any of the Harappan sites belongs to domestic animals. The Harappans also consumed a variety of wild game.

Table 2 gives the plant and fruit remains found at the Harappan sites. This shows that a wide variety of plants were cultivated.

Table 1. Plant Remains from the Harappan Sites

Plant Name	Latin equivalent	Site
1. Rice	*Oryza sp.*	(a) Kalibangan (b) Lothal © Rangpur
2. Barley	(1) *Hordeum vulgare Var. nudum* (2) *Hordeum vulgare Var. hexastichum*	(a) Mohenjodaro (b) Harappa © Kalibangan
3.(i) Indian short wheat (ii) Bread wheat (iii) Club wheat	(i) *Triticum sphaerococcum* (ii) *T. vulgare* (iii) *T. compactum*	Harappa Mohenjodaro
4. Sesame	*Sesamum*	Harappa
5. Mustard	*Brassica juncea*	Chanhudaro
6. Cotton	*Gossypium arboreum*	Mohenjodaro
7. Date palm	*Phoenix sp.*	Harappa

8. Water melon	*Cucumis melo*	Harappa
9. Pea	*Pisum arvense*	Harappa

3. TRANSPORT

In the development of a civilization, harnessing and efficient use of energy is essential. We have evidence that the Harappans used cattle power for transport and wind power for sailing their boats. The invention of wheel helped both the transport and ceramic industries.

Terracotta models of carts are quite ubiquitous, though bronze models have been found only at Harappa and Chanhudaro. Both the lighter *ekka* type and the heavier bullock-cart type can be identified in these models and hardly seem to have changed through all these millennia. Rao has reconstructed three main types of cart from Lothal.

The Harappans also used boats (Figs. 2,3). One of the Mohenjodaro stone seals and a terracotta amulet depicts boats. Rao discovered five clay models of boats from Lothal. Rao reports "a sharp keel, pointed prow and high flat stern. It has three blind holes probably for stern, mast and ropes for the sail". Boats - with sails and without - were in use. Possehl has given a reconstruction of a Harappan boat (Fig. 3). Right now, he is leading (along with Vosmer) the Magan Boat Expedition under which they are building a boat exactly as their ancient counterparts did, using reed bundles, white clay, bitumen, cowhide and boat skin. They will start from Oman and reach Meluhha, the Indian waters in September 2005.

4. STONE & BEAD TECHNOLOGY

The material used for beads was agate, carnelian, lapis lazuli, shell, terracotta, gold, silver and copper. Pressing the paste through thin bronze tubes made fine steatite beads. The Harappans etched the beads by making patterns in alkali paste and then heating the bead till the alkali was absorbed. In the other type, the whole bead was made white with alkali heating and then a black design was painted, perhaps with the copper nitrate solution. Generally the seals were made of steatite.

Bead industry seems to be well developed as shown by the factories discovered at Chanhudaro and Lothal. Beads were made of agate, carnelian, faience, shell, terracotta, gold, silver and steatite.

The large gastropods *Turbinella pyrum* and *Chicoreus ramosus* were cut with a specialized bronze saw that would have been available only in the largest workshops. It is astounding to note that the Indus bronze saw was able to cut the shell as efficiently as the modern steel saws. Bhan and Gowda have made a thorough study of the shell industry.

One famous vessel found at Mohenjodaro is a tall tumbler with concave sides that is similar in shape to ritual columns found in Baluchistan and Afghanistan. This green stone, called fuchsite is rare, but it can occur with quartzite which is common throughout Baluchistan and Afghanistan.

Though the Harappans did not make glass, faience (a sort of proto-glass) was used to make bangles, rings, miniature animals and pots.

5. CERAMIC TECHNOLOGY

The Harappan pottery is mostly wheel-thrown, red-slipped and painted with motifs in black. After the pot was made, it was dipped in a red-slip and painted and then fired. The use of foot wheel, still in use in Sindh and Punjab, can be seen in the flat bases with string cutting marks on the Harappan pots. Only in the Saurashtra Harappan assemblage, a black-and-red pottery was also used. How exactly the bicolour was achieved is still a matter of debate but it is obvious that the supply of oxygen (air) was restricted only to those portions of the pot which were *oxidised* red.

6. METAL TECHNOLOGY

The tool repertoire of the Harappans shows neither the complicated mouldings of Mesopotamia nor the ornate designs of Chinese metal-ware. Except for the specimens of the dancing girls, no human images are available in metal. But these examples do show their competence in the lost wax *(cire perdue)* method of casting. There is plenty of pots and pans in metal in the Harappan assemblages. The main tool types are: razors; leaf-shaped knives with incurved end; sickle blades with externally sharpened edge; chisels; spearheads; thin barbed arrowheads; straight and circular saws; blade-axes; mid-ribbed daggers; drills; and eyed needles. It may be pointed out that needles with eyes on the pointed ends, true saws, circular saws, and hollow drills are the Harappan innovations in the world of instruments.

The Harappans could smelt even sulphide ores, though oxide ores were commonly used. The similarity in the trace impurity patterns of the Harappan artefacts and the copper minerals of Khetri mines may indicate its exploitation. But so far the actual copper workings in the Khetri belt have not been dated beyond c.1200 BCE.

The Harappans used a variety of gold ornaments like beads, armlets, brooches, pendants and ornaments used on headdresses and clothes. The art of filigree (drawing gold wire) and soldering silver and gold tracery shows a high virtuosity. The most remarkable is decorating a metal surface with miniature drops of gold, with each drop (granule) soldered to its designated place, was an immensely difficult technique which the modern European jewellers took several centuries to master.

Harappan Mining Areas. Agrawal applied Friedman *et al's* techniqu*e* to determine the probability of the use of different types of ores by the Harappans by analysing all the then available data. Agrawal's analyses show that both oxide ores and native metal were employed by the Harappans at Harappa and Mohenjodaro, though in some cases they appear to have used sulphide minerals (e.g., Chalcopyrite) also (See Tables 13, 14, 17, 18, 26 and 28 in Agrawal, 1971). As most of the objects analyzed from sites of the Indus Civilisation have been finished copper metal objects, a systematic comparison of Harappan copper artefacts

with copper ores from the variety of sources available has been sorely neglected. The actual mineral fragments have been reported from the Harappan are: chrysocolla and chalcopyrite, hematite, löllingite (arsenic and iron), antimony, cinnabar (sulphide of mercury), cerussite (carbonate of lead), galena etc.

There are four major regions that could have supplied the copper ores or processed metal used by the Indus metalsmiths: 1.The area of Baluchistan and Afghanistan; 2. the inland mountain range of modern Oman; 3. theAravalli Mountain Range of Rajasthan; and 4. eastern Iran. The copper deposits in Rajasthan and the Aravalli mountain ranges have been discussed by SanaUllah, Hegde, Agrawal, Asthana, Hegde and Ericson, Rao, and Hooja, but only a few analyses of ore samples have actually been published.

The major sources of tin used during the Harappan Phase probably derive from what is now modern Afghanistan. Some alluvial deposits are reported in western Afghanistan in the Sarkar Valley south of Herat and major deposits occur in the central regions north of Kandahar. Other tin deposits occur in northern Afghanistan near the ancient lapis lazuli mines. It is unclear who was controlling the access to the tin resources during the third millennium BCE, but the largest settlements of the Helmand Tradition, Mundigak and Shahr-i-Sokhta, are located at strategic points along the trade routes that would have connected these resource areas to the consumers in Mesopotamia. The Harappan Phase site of Shortugai is located at a northern source and may reflect a competitive situation where the Indus peoples chose to develop their own mining and distribution rather than rely on alliances with the sites of Mundigak or Shahr-i-Sokhta. With the discovery of rich cassiterite bearing (up to 1.5% tin) quartz-porphyry in the Tusham hills, near Bhiwani, Haryana, the possibility of bronze ingots being also supplied from Ganeshwar, become more probable. But as smelting operations have spatial constraints of nearness to the old mines; these sites are naturally located close to the Rajasthan copper mineral occurrences. There is some evidence of sharp edged tools being made of bronze in the Harappan towns. Keeping in view the highly regulated nature of the mature Harappan towns with their rules of town planning, civic sanitation, standardisation of weights and measures we should not be surprised if some control was also exercised on the tin/arsenic content of the bronze ingots exported to the Harappan towns. With the discovery of Tusham tin mines nearby it now becomes more probable.

It is estimated that in the Mardan–Kudan section there is a reserve of 28 million tons and in the Dariba region 0.5 million tonnes. The main mineral is chalcopyrite ($CuFeS_2$). Therefore, import of copper from Oman does not make much sense unless marine transport was far cheaper than even short distance overland transport. There is every possibility of the Ganeshwar Complex itself being the much talked about Meluhha of the Mesopotamian texts! Miller has emphatically said that none of the Harappan sites has any copper smelting evidence, though there is melting evidence.

Fragments of gold leaf or tiny beads are not uncommon in the excavations of Harappan Phase sites; the gold leaf may be derived from beads or other objects that were covered with

decorative gold, and the tiny beads undoubtedly derive from broken necklaces. The proportion of gold to silver was between 91% and 94% in the five gold objects, but further analysis is necessary to determine if other elements are present. Two "gold" objects from Lothal have been analyzed (by BB Lal, chemist) which contain 33.45% and 41.48% silver, but no copper, nickel, lead, or zinc.

Making Copper Artefacts. The only published terracotta moulds are from Lothal, and might be fragments of open moulds, although Rao calls them "crucibles". The copper/bronze objects indicate that some tools were definitely made by open or bivalve casting. In addition, the modelled forms of the famous metal figurines of animals and humans can be attributed to the lost wax casting. Fabrication includes shaping, via forging, turning and drawing, cutting, cold and hot joining, and finishing via planishing, filing, polishing, colouring, engraving, and so forth. The metal can be worked while cold or hot, but at a heat below the molten state. Ingots (either secondary or smelting ingots) can be worked either into sheet form or directly into a finished object. In its broad sense, shaping is the controlled mechanical stretching of metal. This includes stretching by forging, including sinking and raising; by spinning or turning; and by drawing. The most common form of shaping was found to be forging, "the controlled shaping of metal by the force of a hammer", usually on an anvil or stake. There is some evidence of forging during the Harappan Phase, both from traces of tool marks and from metallography. The Indus peoples forged objects both from castings (including bar or block ingots and semi-finished shapes) and from sheet metal. For example, chisels, which are one of the most numerous tool types, appear to have been forged from cast bars. Metallographic analyses of other edged tools confirm that at least some of these tools were cast and then forged. Thin razors are thought to have been cut from copper sheets, and then forged to a sharp edge. Sinking and raising was also employed to form vessels. Sinking is the forming of metal by hammering from the interior of an object into a depression in an anvil, while raising is hammering from the exterior of the object over a shaped stake or form.

Joining Metal. There are very few examples of cold joining, comprising primarily the use of rivets to attach metal handles to metal vessels. There is evidence for soldering of gold and silver and an example of pouring molten copper metal over a joint to attach a copper handle securely to a copper vessel.

Alloying. Tin is employed (optimum range 8-12%) to improve the hardness and ductility of copper. We however find that there is a great variation in the concentration of tin in the Harappan artefacts. This may indicate either lack of control in alloying or use of a mixture of tin and copper ores. Agrawal found that out of the 177 analyses of the Harappan artefacts he examined, only 30% contained more than 1 % tin, rest of the 70% were unalloyed. This may perhaps indicate poverty of tin resources.

Harappan Furnaces. They occur in different forms, such as oval, oblong, and circular and pear-shaped. Some are raised with mud bricks and some are cut into the natural soil. A fine paste of clay is applied for smoothness along the walls of the pit. Generally, these types of furnace will be jutting out nearly 7 to 9 cm above the ground level. Oval shaped furnace is

more common. From Mohenjodaro Mackay found a quantity of copper ore in small pieces together with a little piece of lead and it is quite possible that a metal-smith worked here with a furnace in close vicinity. From Harappa, sixteen furnaces, all situated in trench IV, mound F, were discovered. They are of three kinds:
(a) Part of round pottery jar.
(b) Cylindrical pits dug in the ground with or without brick lining.
(c) Pear-shaped pits dug in the ground with or without brick lining.

Possehl has illustrated a funnel shaped up-draft kiln (Fig. 4).

At Tarkhan-wala-Dera mud bricks having four courses were used for construction. An oval shaped structured, possibly furnace, which was partly jutting out and partly underground yielded Harappan pottery. The top of the wall was covered with mud. One complete dish was obtained from this structure.

At Kotla-Nihang Khan in the eastern Sector, several such kilns were noticed in a row, partly underground and partly jutting out of the surface. From one of these kilns were recovered fragments of three terracotta bangles. A similar kiln was also noticed at Bara and it yielded a small painted vase.

J. P. Joshi has also reported oval structures of burnt earth from Bhagwanpura, Dadheri, Nagar and Kalpalon. Similar small kilns or furnaces were also found at Hulas in western Uttar Pradesh. Two small furnaces one circular and other oval shaped were unearthed from the Harappan levels. Two kilns were noticed at Lothal. One of them was circular on plan and has two chambers one above the other. The brick wall and floors of both the chambers were plastered with mud; these were possibly used for baking pebbles and beads of semiprecious stones.

7. STANDARDIZATION AND METROLOGY

The uniformity and standardization of the Harappan artefacts has baffled many an archaeologist. It assumes both an amazing administrative control over a territory of over almost a couple of million square km and also over production and distribution. The shapes and designs of pottery, the types of copper tools, the weights and measures, the standard size of bricks (ratio 1:2:4), uniform layouts of the cities, etc., clearly indicate that they had realized the advantages of standardization.

A shell scale from Mohenjodaro and of ivory from Lothal indicates the Harappan measures of length. The Lothal scale has a length of 128 mm. The smallest divisions are 1.7 mm and the next unit is 33.46 mm (1.7 X 20). The Lothal scale is divided decimally. On the Mohenjodaro and Lothal scales a bigger unit of 67.056 mm can also be discerned. Both foot (13.2" or 33.5 cm) and cubit (20.5"±0.3" or 52±0.5 cm) seem to be in vogue, as indicated by the measures of buildings and roads. For example, the main walls of the Harappan granaries measured 30 cubits and their widths 10 cubits; some houses of Lothal measured 40 X 20

units of the Harappan foot. Rao has pointed out that the 17.7 mm Harappan division is very near the traditional *angula* measure of 17.86 mm of the *Arthasastra.*

Similarly the Harappan cubical weights show remarkable accuracy of standardization. In the lower denominations the system is binary: 1, 2, 1/3 X 8, 4, 8, 16, 32, etc., up to 12,800 which is comparable with the traditional Indian ratio of 1:16 (1 *seer* = 16 *chhattack*s). The weight unit is equivalent to 13.625 gm. In the higher weights they have followed a decimal system, with fractional weights in one-thirds.

8. ARCHITECTURE

The Harappan elite do not show any megalomaniac architecture, or sepulchral luxury items, unlike China or Mesopotamia. This typical trait of humility even amongst the elite is perhaps uniquely Indian. Of course, there are fortifications and so called citadels both from the Mature Harappan and Early Harappan levels of Kalibangan, Mehrgarh VIIA, Kot Diji, Rehman Dheri and Nausharo. The Mature Harappan citadels and fortified sites are evident at Harappa, Mohenjodaro, Suktegendor, Alimurad, Gazishah, Kalibangan, Banawali, Surkotada and Dabarkot. A variety of large structures had been called granaries, assembly hall, college building etc., but their exact purpose is not known. The hallmark of the Harappan towns is their planned layout, though Possehl has raised some doubts about them. In Mohenjodaro a large number of mud brick platforms were raised over which burnt brick houses were built. This was obviously done to prevent salts from moving through capillary action into burnt bricks. Dholavira presents a three-fold town planning with elaborate defence system, gateways, storm drains and interconnected reservoirs and dams. A warehouse at Lothal is built on a podium of mud brick of 48X40X4m with 12sq blocks in a grid pattern. The burials also show considerable variation in their architecture. Dholavira has yielded even cairn circles, cenotaphs etc which are reminiscent of the megalithic tradition. Depending upon their requirement the mortar was chosen: mud, lime plaster and gypsum cement were used.

At Dholavira, the excavator Bisht has identified the open area between the Castle and Bailey on the one hand and the Middle Town on the other as a stadium. The inhabitants of the Lower Town could have entry into the stadium through a gate in its eastern enclosure wall. It may be mentioned here that Shubhira Pramanik has also reported two stadia from the Harappan site of Juni Kuran (Dist Katchchh).

As JP Joshi discusses architecture in details in his paper, it is not being dealt in detail here.

9. HYDRAULICS

The bathing facilities in each house inform us that washing and cleanliness were important to the Harappans. The many wells throughout the city were sources of new, pure water, essential for effective cleanliness. The drainage system served to move the effluents away from the houses, below ground, safely out of the way and out of sight, in brick-lined channels that prevented contamination.

It seems that the Harappans were aware of the pollution caused by sullage draining into the rivers. Therefore, they used wells and reservoirs, which were built within the cities to ensure clean drinking and bathing water. At Mohenjodaro numerous wells were dug throughout the city and maintained for hundreds of years. These 10 to 15 meter deep wells were lined with specially made wedge-shaped bricks to form a structurally round cylinder that would not cave in under pressure from the surrounding soil.

Many neighbourhoods had public wells along the main streets for animals and the general public. The drains for collecting rainwater were built separately from drains used to take away sewage water. At Mohenjodaro, most houses had at least one private well. On the basis of the number of wells found in the excavated areas, Jansen (2002) has calculated that the city may have had over 700 wells. In contrast, Harappa may have had as few as 30.

Bathing platforms with drains were often situated in rooms adjacent to the well. The floor of the bath was usually made of tightly fitted bricks, often set on edge, making a watertight floor. At Mohenjodaro and Harappa tapered terracotta drainpipes were used to direct the water out to the street.

The HARP excavations at Harappa reveal latrines in almost every house, though it seems that the early excavators at both Mohenjodaro and Harappa did not pay much attention to this essential feature of the Indus cities.

The baked brick drains connected the bathing platforms and latrines of private houses to medium-sized open drains in the side streets, which flowed into larger sewers in the main streets. The sewers were covered with bricks or dressed stone blocks. The well laid-out streets and side lanes equipped with drains are one of the most outstanding features of the Indus cities.

Dockyard. The so-called "Dockyard" is located on the eastern side of Lothal in Gujarat. Constructed of baked brick, the "Dockyard" is nearly rectangular in shape, 219 X 37 m in size. The brick walls of the sunken enclosure are 4.5 m high. A platform borders the town side and permits easy access to the warehouse area on the Citadel. The precise function of this brick lined enclosure is still a controversial issue.

Dholavira Hydraulics. Dholavira, in Gujarat, is an extraordinary example of an elaborate hydraulic system where they provided storm drains, potable water reservoirs, and sullage water drains – all separated from each other.

Bisht informs us that both the streams - Manhar and the Mansar – were used to create a series of reservoirs. The Manhar had three and the Mansar two dams, raised across their beds, besides several check dams further upstream to reduce the force of the flowing water. The people of Dholavira created within the city walls nineteen or more reservoirs. The reservoirs enclosed the L-shaped city from three sides: the northern, western and southern,

but only partly on the east. The city with its reservoirs was secured by a quadrilateral fortification. The city walls also provided strong embankments for the reservoirs. Bisht, the excavator, estimates that, out of the total area of about 49 hectares on which the Harappan city stood in its heyday, the reservoirs accounted for about 10 hectares, 20% of the total area. The eastern reservoir is the largest and grandest that Dholavira has yielded so far with the longer axis of the reservoir measuring 73.50 m, depth varies between 7.50 to 7.20 m.

*Storm Water***.** The Harappan engineers provided for drinking water reservoirs, storm water drains and also the sewage lines, making sure that they did not leak into each other. Bisht reports that the citadel has yielded an interesting network of drains coming from different directions and ultimately connected to an arterial drain that runs under the Broadway which, in turn, divides the walled area into two roughly equal halves. The larger drains, large enough to allow a person to walk through them, let out the monsoon run-off. There are two large drains: one originating from a salient beside the east gate and the other from the north gate. The former is connected to a stone-paved platform provided atop the eastern fortification wall near the said gate. Obviously, the Harappans designed the drains to store the rain-water in reservoirs, unpolluted from the household waste.

10. INNOVATIONS

The technological skills of the Harappans are not only reflected in their accurate and scientific system of weights and measures, but also in their new innovations. They made circular saws, true saws (with teeth and body set alternately from side to side for the maximum efficiency of cutting), needles with the eye at the pointed end, and fine tubular drills. The Harappans were the first to make these instruments, some of which were re-invented three thousand years later in Europe!

For survey and measuring angles, they had a device, which was identified for the first time by Rao at Lothal. It is made of shell. Rao says, "It is a hollow cylinder with four slits on each of the two edges. When placed on a horizontal board it can be used almost as a compass in plane table survey for fixing the position of a distant object by viewing it through the slits in the margins. The lines so produced pass through the central point. If the opposite slits on one side are joined by cords they cut at right angles, and if all the cords passing through the slits on both the margins are drawn on the same plane as shown . . . they intersect one another at the centre and the angles so formed by the eight lines measure exactly 45° each. Obviously this instrument must have been used for inland survey and for fixing alignments of streets and houses". This object is not unique at Lothal but was found at Mohenjodaro also and was mistakenly listed as an ornament.

11. LEGACY

There is no doubt about it that at the end of the II millennium BCE a break and a drastic change was writ large on the archaeological evidence. On the other hand, there is ample evidence of cultural and technological continuity into the later periods. Some scholars have

emphasized the break and others, the continuity. The need is to take a balanced and holistic view.

In a traditional society like ours, hoary traditions continue along with newly acquired fashions and technologies. A closer look clearly shows an old, Harappan sub-stratum, on which the edifice of the present Indian culture stands.

The (Hindu) religion is basically iconic and not animistic. The *pasupata, yogisvara, trimukha* aspects of the famous seals have been identified as proto-Siva, or even *proto-Mahisa.* The *linga* worship can only be traced to the Harappans. The importance of *pipal (Ficus religiosa),* swastika, and water ablutions in today's religion can be traced back to the Harappan preoccupation with water rituals and the emphasis on the *pipal* motif do suggest a continuity of the religious beliefs. The enigmatic terracotta figures do suggest yoga-like postures.

In a third millennium BCE context, when communication and transport must have been difficult, the credit for unifying the north and west of the subcontinent goes to the Harappans. They were the first to achieve this unification of a society with so much diversity.

The secular objects like the typical Harappan house plan of a central courtyard surrounded by rooms (it has been found by air-conditioning experts to be best suited for Indian climate) seems to have continued from the Harappan times. The middle class had medium-sized houses, but with a characteristic layout. These consisted of a courtyard, on three sides of which there were rooms and the wall on the fourth side had a gate, opening on the street. It is interesting to note that an identical planning of the house is still prevalent in the villages, though now concrete-made.
Even the *tandoors* and *chakla* (platter) used by the Harappans were similar to the ones being used today.

At Banawali Bisht found a 'touchstone bearing gold streaks of different hues which was evidently used to test the purity of gold; the same method is applied by the goldsmiths even to this day. At Harappa was found a three-in-one toiletry gadget made of copper. It consists of a tweezer, a small pointed rod and a somewhat flattish object. A similar three-in-one piece in metal is available even today in the market.
The binary system of weights of the Harappans followed 1, 2, 4, 8. 16, 32, 64....... 128(X), with fractions in one-thirds. Till recently, the Indian 1 seer = 16 chattacks and 1 rupee = 16 annas basically followed the same binary system. In the Kumaun hills 16 *mutthis* make one nali (50 nalis equal 1 hectare). Even the *Arthasastra's (angula* 17.8 millimeters) seems to have been derived from the Harappan measuring unit of 17.7 mm.

Ch 3

Harappan Architecture And Civil Engineering

(book summary)

Jagat Pati Joshi

In the field of traditional knowledge systems, the Harappan civilization which flourished during the 3^{rd}–2^{nd} millennia BCE ranks amongst the four widely known civilizations of the Old World and covers appreciably larger area than in the early Dynastic Egypt or Sumer. Like the other Old World Civilizations, the Harappan civilization seems to have grown from the skilful utilisation of the fertile river systems and their valleys in the north-western region of Indo-Pakistan sub-continent. The Harappans have given systematic town planning, fortification of citadels, elaborate drainage system the idea of establishing of granaries and surplus economy, standardization of brick sizes, weights and measures, geometric instruments e.g. right angles, linear scale and plumb bob are the principal gifts of the Harappans to the succeeding cultures through the ages. It was the Harappans who gave the idea of welfare of the workers for the first time by establishing workmen's quarters and now it has become a necessity. Different types of hydraulic architecture is another legacy of the Harappans besides many other in social, economic and religious fields.

AIMS AND OBJECTIVES OF THE BOOK

The book aims to bring out the various aspects of Harappan architecture and civil engineering with a suitable background introducing the Harappan civilization, its different nomenclatures, its distribution of sites in the Indo-Pakistan subcontinent and possible origin, forms and chronology. The planned architecture of the cities of mature Harappan people catered the needs of all classes of its society a factor which distinguishes it from the other contemporary Mesopotamia and Egyptian civilizations. So far, the development of architecture of citadel and residential areas is concerned there are sites wherein the development from rural to urbanized architecture could be gleaned. The book is divided into ten chapters and has 146 illustrations and a useful bibliography at the end.

CHAPTER I
HISTORY OF DISCOVERY

On the trade route from Lahore to Multan, when Charles Masson first saw the ancient mound at Harappa in 1826 he hardly realized that it contains remains of one of the earliest civilizations of the world. Lt. Alexander Burns, the British King's emissary to Maharaja Ranjit Singh in 1831 stopped for a while at Harappa, gazed at the ruins, and went away to Lahore. It was in 1862, that Alexander Cunningham, the first Director General of the Archaeological Survey of India, during his excavations, found pottery and a seal at Harappa. It was Major Clark who found a seal with a humpless bull and the engraved letters on it which Cunningham at that point of time, called foreign to India. Thus, the discovery of this

great civilization began. Actual excavations were started in 1920-22 by Daya Ram Sahni under Sir John Marshall at Mohenjodaro and by R.D. Banerjee at Harappa. N.G. Majumdar had made a survey of the Sind region. He explored and excavated many sites in the Indus basin. In the succeeding decades after 1922, a large number of sites were discovered in the Indus Valley.

Nomenclature

The main centres of this civilization, were found, at Mohenjodaro, District Larkana (Sind, Pakistan) and Harappa, District Montgomory (Panjab, Pakistan). Besides these, Dabarkot, Nokjoshahdinjai, Chanhudaro, Lohumjodaro, Amri, Pandiwahi, Aliumurad and Ghazi Shah in Pakistan yielded remains of similar culture. Since many of these sites were located in the Indus basin, scholars named this civilization as Indus Valley Civilization. This was due to the fact that civilization was then limited to the Indus Valley proper.

Before the partition of India (1947), comparatively few sites of Harappan civilization (named after Harappa, the first discovered type-site), more popularly known as Indus Civilization, had been discovered. However, by that time the results of excavations at Mohenjodaro, Harappa and Chanhudaro were already published and the explorations carried out in Punjab, Sind and Baluchistan by Stein and Mazumdar were also available in the *Memoirs of the Archaeological Survey of India*. Thus, the civilization was confined more or less to the limits of Indus basin and was considered to have ‘stagnating’ cultural traits.

Research after Independence, changed the position regarding the spatial extent, culture-contents, regional variations etc. of the Indus Civilization. The evidence gives a plethora of information regarding environmental factors, regional adaptations and variability in settlement patterns and social and religious fabric of the civilization. The entire scenario is based on material evidence which tends to give new insights for understanding the Harappan Civilization, its settlement types, planning and architecture. During the last eight decades, due to the consistent efforts of archaeologists, a large number pre-Harappan, Harappan and the Late Harappans sites have been discovered in India and Pakistan and most of these newly discovered sites are in the Sarasvati system. Some archaeologists have now come out with such nomenclatures as ‘Indus-Sarasvati Civilization’ or ‘Sarasvati-Hakra Civilization’.

Spatial Extent

The area of distribution of Harappan settlements runs broadly from Sutkagendor in Makran (Pakistan) and Desaipur and Dholavira in Kachchha in the west, Manda in southern Jammu (J&K) Rehman Dheri in the north Pakistan Daimabad in Maharashtra in the south and Hulas in Saharanpur District in U.P., in the east. It covers an area of about two million sq.kms.

The excavated sites of Harappan Culture have yielded a substantial number of radiocarbon dates. As a result, the age range for the Harappan culture is between c. 2600 and 2000 B.C.E.

By and large, Pre-Harappan/Early Harappan and Harappan sites are located along major rivers. Contrary to this. Late Harappan sites are found along tributaries, and in the upper reaches of these rivers. For convenience sake, the area covered by Indus Civilization can now be divided into six zones:

(1) Punjab (type site: Harappa); (2) Rajasthan, Haryana (type site: Kalibangan) (3) Bahawalpur (type site: Ganweriwala) (4) Sind (type site: Mohenjodaro); (5) Baluchistan (type site: Kulli Harappan phase) ; (6) Gujarat (type sites: Dholavira, Lothal).

Of the six zones, the first four have a number of sites where the Harappan Culture is found stratigraphically late; than a variety of Chalcolithic cultures. These have been termed as Pre-Harappan/Early Harappan sites of formative stage or of antecedent culture. Practically in every zone there are three kinds of situations: (a) where there is a clear stratigraphic break between the Pre-Harappan and Harappan Cultures, although the two complexes are found in mixed form through a number of layers subsequent to the layer marking break, e.g. Kot Diji and Kalibangan, (b) where the stratigraphic break is not clearly marked and a situation of overlap exists, e.g. Banawali; Kalibangan, Dholavira, (c) where the Harappan Culture never reached the site of Pre-Harappans, such as Jalilpur, Sarai Khola, etc.

CHAPTER II
ORIGIN, FORM AND CHRONOLOGY

The Harappan civilization is available in a full-fledged form in the Indus Valley, Rajasthan and Gujarat. A Ghosh (1981) has said, "... this itself lends to it a peculiarly romantic charm while death from unidentified source is understandable, unnatural birth is an unnatural phenomenon". M. Wheeler (1946) had postulated that 'opportunity' and 'genius' might be responsible for the origin of this civilization. One thing is certain that it did not appear with a bang. Various theories have been propounded regarding the 'origin' and 'form' of the civilization and it would be clear that its origin cannot be explained by a single factor whether 'colonization' or 'acculturation'. Pattern of culture contacts between the Indus plain and the adjoining region on the west varied according to both time and space, with the result that we often have a spectrum of intermediary situations between the two opposite extremes, viz. 'colonization' and 'acculturation' leading to regional development. The latest evidence from sites such Banawali, Dhalewan, Dholavira, Kalibangan, Kunal and in India; Amri, Balakot, Ghazi Shah, Kot Diji, Lewan, Mehrgarh, Nausharo, Rehman Dheri, in Pakistan show independent growth except economic interaction. Growth and changing civilizational process spread from the seventh millennium to the third millennium B.C.E. in which many sites were involved. Some of these sites have shown architectural origins of the mature Harappan period which shows a development process. The beginnings of systematic planning fortification, for the settlements could be gleaned. This appears to be a plausible hypothesis for the origin of Indus Civilization. The process is widespread within the northwestern part of the subcontinent.

Recently an intermediate phase between the Early- Harappan and Harappan has been identified at Banawali and Dholavira by the excavator. Similarly the evidence at Padri in

Saurashtra is equally interesting. The recently excavated Pre-Harappan, Early Harappan material from Kunal, District Hissar, Haryana, is most revealing wherein two crowns, armlets, bangles, necklaces and pendants of various size in precious metals (gold and silver); 12000 beads of carnelian and steatite seals having Harappan shape and style but without the figure of typical animal and pictographic script have been found.

Of course, the Pre-Harappans / Early Harappans had the knowledge of building of citadels, knew the dish-on- stand form in pottery and were acquainted with fish scale and *peepal* leaf design, but did not have the 'state of urbanization' . They had some sort of distant trade mechanism also. The 'horned design' and the 'pipal leaf are well depicted in the Early Harappan levels at Kalibangan and Banawali. Perhaps this appears to be a precursor of the horned deity of the seals of Indus. The concept of use of seals was there, but without writing. Predating Indus levels, seals from Mehrgarh and Nausharo are made of clay, bone and ivory. Seals from Rehman Dehri have a small knob also. At Kunal steatite seals have been found with a geometric motif and an incipient boss at the back. Kunal has bone tools and micro-blades of chalcedony. Triangular cakes and dice heads are also available besides a short blade industry. Some of the graffiti found at Rehman Dheri, Kalibangan, Amri, etc. are akin to Harappan ones. These elements are found in the subsequent Harappan Culture. The genesis and growth of the urban architecture of the Harappans from various discoveries from about twenty sites in the Indo-Pakistan sub-continent which came into existence prior to the Indus civilization and continued with it for some time. Lal (1997) has rightly pointed out that the mature 'Harappan revolution' took place within Kot Diji, Rehman Dheri, Banawali triangle between 2600-2500 BC. He has very carefully analysed the radiocarbon dates of the Harappan Civilization and has ascribed a time bracket for the mature Harappan between *Circa* 2600 BC to 2000 BC.

CHAPTER III
SETTLEMENT PATTERNS

Location of settlements

Settlement patterns of the Harappans were conditioned by the behaviour of the river providing an active flood plain and ecology, navigability of the river for internal trade, climate, accessibility to natural resources and trade routes, both internal and external. Development of a city is greatly dependent on these factors. The Harappan settlements in its extant form narrate the history of its construction, the force that brought it into being, its successive building phases, its purpose and the people behind its construction and other natural causes of its decay and distraction.

The settlements types and their positioning also reflect the importance from the point of view of distant marine trade e.g., Lothal and Mohenjodaro, Chanhudaro and Sutkagandor and Harappa; for trade with the hinterland etc. In the excavated sites, the Harappan settlements are found built of mud bricks, burnt bricks and chiselled stones. While use of stones and mud bricks is limited to Kachchh and Saurashtra area, mud bricks are largely used at Harappa, Kalibangan, Lothal and Banawali besides burnt bricks. The size of bricks remained the same

everywhere. The ratio of brick size is 1:2:4. The use of stone in making the houses and defenses in Saurashtra and Kachchh was perhaps due to the easy accessibility of stone in the neighbourhood. It may be seen that there is considerable regional variation in the use of building material for architecture based on the availability and climatic conditions.

The Ghaggar River system, with its own network of tributaries, along which lie hundreds of sites was a mighty river system. It was a more stable river system than the Beas, Sutlej and Ravi, which were erratic in their behaviour. It provided a consistent and better line of communication through the Sirhind Nala between Punjab and Rajasthan for getting timber from the areas of present Himachal Pradesh. The Ghaggar-Sarasvati-Hakra system had three major ‘economic pockets’. The first was on the north along Sirhind where in an area of 120 km^2, in Mansa District, Punjab, seven cities, six towns and fourteen villages (on the basis of the size of mounds and cultural deposit) have been located at a distance of 3-5 km are indicative of an ideal situation of an urban complex and commercial interaction. The second or the central pocket was in Bikaner Bhawalpur area where 400 sites have been located in an area of 1000 km from Yazdan to Derawar Fort belonging to the Pre-Harappan and Harappan times. The third, southern one, in Kachchh, which is geographically half way between Sind and Gujarat and has a concentration of about 50 sites of the Harappan and Late Harappan periods. These three ‘economic pockets’ in the ‘culture empire’ of the Harappan provided a strong economic base that is the foundation of the ‘urban boom’. It may thus be inferred that Harappan settlements are largely located along the major and perennial rivers. It is also seen that the urban phase of the civilization had technological potentialities to raise high defenses and platforms which needed resources, builders, planning, engineering skill and instruments and a large man-power. It has been reported that 21 rural Harappan sites have been identified in District Mahesna, Gujarat besides Valabhi which has yielded evidence of a cattle breeding centre during the Harappan times.

It has been observed that the settlement size of matured Harappan people are much bigger than the early Harappan sites. At times, there is a big gap between the sites Mughal has anticipated a four tier hierarchy in the settlement pattern of early Harappans. In India, upto this day there are mounds having early Harappan and Harappan cultures but in Pakistan there are separate mounds of early Harappans / pre-Harappan also.

CHAPTER IV
SETTLEMENT TYPES

The excavated sites give a fairly good idea of settlement types of the Harappans and the public architecture involved. At this stage, it may be pointed out that planning, orientation of streets, houses, defence walls have been seen in the early Harappan sites at Kalibangan, Mehrgarh VII A, Kot Diji, Rehman Dheri and Naushero which has been dealt with as back drop for the urban development that followed.

The following matured Harappan sites give evidence of town planning, drainage system, defences and water management of an organised urban society :

(i) Harappa and Mohenjodaro, (ii) Kot Diji, (iii) Rehman Dheri, (iv) Naushero,
(v) Kalibangan (Fig. 1), (vi) Banawali, (vii) Lothal, (viii) Surkotada, (ix) Dholavira, (x) Rojdi, (xi) Kuntasi (XII) Padri (XIII) Bagesra.

CHAPTER V
TOWN PLANNING

The various aspects of town-planning at the above sites have been discussed systematically : 1. Fortification and gateways (Fig. 2) 2. Planning of the township 3. Streets (Fig. 3) 4. Drains 5. Bathing platforms 6. Platforms 7. Types of houses, some outstanding buildings of the Harappa Civilization—(a) Granaries at Mohendjodaro and Harappa (b) The Great Bath of Mohenjodaro (c) Dockyard and Warehouse at Lothal (d) The College Building at Mohenjodaro.

CHAPTER VI
HYDRAULIC ENGINEERING

The Harappans were great hydraulic engineers. They were doing well and canal irrigation. Evidence of canal irrigation from Haryana and Rajasthan is available during the early and mature Harappan times. Wells at various sites, tanks (Fig. 4) and construction of check Dams at Dholavira attest to it. Storm water and city drainage system was well-known. The dockyard at Lothal
(Fig. 5) and Great Bath Complex at Mohenjodaro are best examples of hydraulic engineering.

CHAPTER VII
RELIGIOUS ARCHITECTURE

Earlier no temple was found at Mohenjodaro and Harappa. Now at Edith Shahr complex, find of a Zaggurat type of structure, having atop a platform with drains; Damb Saddats evidence of a stone platform with drains and stone cairn with a skull, Kalibangan has given the evidence of fire altars and a sacrificial cistern with animal bones, fire altars and bathing platforms found at Lothal fire altars and apisidal temple like structure at Banawali lead to the emergence of religious architecture of Harappans.

CHAPTER VIII
BURIAL ARCHITECTURE

Various types of burial architectural forms though simple are available. Extended burials in coffins at Harappa, brick lined graves at Harappa and Lothal, *Bhumigriha* type burial at Kalibangan, simple memorial burials at Surkotada and Dholavira with a cairn or stone slab at the top are described.

CHAPTER IX
GEOMETRY, TECHNICAL TOOLS, BUILDING MATERIAL, TECHNOLOGY OF BUILDINGS AND KILNS

Geometrical instruments like linear scales, plumb-bobs, right angles of the Harappans are remarkable, which they used for town planning, knowledge of geometry was known. They followed decimal system. Weight and measures have binary systems. House building technology, building materials and foundation of structures as practised by Harappans has been discussed besides mortar, bonding, plaster, pavements, doors and windows and various types of Kilns used by Harappans are also mentioned with some details.

CHAPTER X
DEURBANIZED HARAPPANS AND THEIR SETTLEMENTS

Finally, deurbanized Harappans and their architecture is briefly dealt with in Sind, Gujarat, and northern Deccan and in the eastern domain in Haryana, Punjab and western U.P. The architectural remains at Hulas, Bhagwanpura and Daimabad are discussed to show the process of devolution in the post urban phase.

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Chalcolithic Crafts and Technologies of the Indian Subcontinent

By Vasant Shinde and Shweta Sinha Deshpande

Introduction

Technology is a society's systematization of knowledge and techniques (*craft*) for making and doing things and is concerned with the fabrication and use of artefacts. It can be the application of scientific knowledge to the practical aims of human life or can be the mechanism for change and manipulation of the human environment. It is thus a social phenomenon that cannot be disassociated from the society in which it exists.
Technology can be seen from the introduction of a stone tool in the Lower Palaeolithic times around three million years ago. The rate of technological change that took place prior to the introduction of farming was slow and was in response to only the most basic human survival needs, i.e. the search for food and shelter. The dates for the beginning of Early Farming communities differ from region to region. The Early Farming period is referred to as either Neolithic or Chalcolithic. The Levant region, one of the most fertile regions of the world in West Asia is considered to have witnessed the gradual process from Hunting-Gathering to incipient agriculture sometime around 12000 to 15000 year ago. The various technologies that were developed then spread in all directions to far off regions and are believed to have entered the North-West of the Indian subcontinent through the Bolan Pass around 7000 BC.

Prior to the twentieth century when the systematic research on Protohistoric cultures began, most Eurocentric historians were of the opinion that settled life began in the Indian subcontinent around the 6th or 5th century BC, during the period between the Stone Age and the Early Historic that is considered to be a "Dark Age." However, the discovery of the Harappan Civilization in the 1920's and Chalcolithic in the 1950's pushed back the antiquity of settled life in the subcontinent by two thousand years in one stroke. This is considered to be the twentieth century's greatest archaeological discovery in the subcontinent. The development and spread of agriculture and pastoralism in ancient India was complex and took more than 9000 years, including technological breakthroughs in pottery, metalworking, bead manufacturing, monumental architecture, etc.

Early Farming Communities

The Indian subcontinent has all the favourable ecological conditions necessary to give rise to the early farming communities (Fig. 1). The region witnessed two independent origins of village economies along with the associated technologies, which evolved from the early phases of village societies into developed and mature complex villages and early cities. Hence, it is important to trace the ongoing cultural process in the region. On the basis of

material culture and technologies in use, the Chalcolithic (early farming stage) of India has been sub-divided into Early, Mature and Late phases. The earlier beginnings (approximately around 7000 BCE) are seen in the northwest regions of Afghanistan and Baluchistan, possibly as a result of the influence coming from Southwest Asia. Similar development slightly later in date was witnessed in parts of western India, southeast Rajasthan in the Banas River basin and the Mid-Ganga regions. In the rest of India the development of village-based culture started in the later part of the Mesolithic phase and continued into the Neolithic and Chalcolithic between 3500 and 1000 BCE. The declined phase of the Chalcolithic has been properly studied at the site of Inamgaon in the Bhima basin of the lower Deccan region. The Chalcolithic phases in Central India, the Deccan and the South India have been systematically studied by Deccan College under the leadership of H.D. Sankalia. Unfortunately, the eastern and north-eastern parts of the country have not been subjected to systematic archaeological research.

The large numbers of Chalcolithic cultures identified in the subcontinent have been classified into ten regional traditions:

i. Baluchistan and adjoining regions (beginning from 5th millennium BC)
ii. Padri and Prabhas Patan traditions of Saurashtra (4th millennium BC)
iii. Anarta tradition of North Gujarat (4th millennium BC)
iv. Ganeshwar-Jodhpura of Northwest and western Rajasthan (4th millennium BC)
v. Ahar tradition of Mewar (4th millennium BC)
vi. Kayatha and Malwa traditions of the Malwa Plateau (3rd millennium BC)
vii. Savalda and Jorwe traditions of the northern Deccan (3rd millennium BC)
viii. Neolithic/Chalcolithic traditions of eastern India including Mid Ganga region (4th millennium BC)
ix. Ochre Colour Pottery/Copper Hoard tradition of North India (3rd millennium BC)
x. Narahan culture of eastern Uttar Pradesh (towards the end of 2nd millennium BC)

Each of these is characterised by attributes of the agro-pastoral economy, trade, social, political and economic stratification, and there are also subtle differences among them in styles of pottery, the level of technological development and the origin and evolution of these techniques.

The earliest evidence of agriculture and pastoralism in South Asia comes from the site of Mehrgarh, located on the north Kachi plain at the foot of the Bolan Pass (Jarrige, 1984). The region includes the Kachhi plain at the mouth of Bolan Pass, the Quetta valley, the Khozdar area in the Kalat plateau, the Kotwa region, the Bela area, the coastal plain of Sonmiani Bay and the Turbat oasis. It is a buffer zone between the Iranian plateau and the Indus Basin and therefore significant from the point of the development of early village cultures which could have moved west from the Iranian plateau as a result of agricultural viability. Barley-wheat cultivation and cattle and sheep/goat domestication, similar to that of West Asia, dominated the economy; hence, the foreign influence for the first villages within the subcontinent (particularly in the north-west) cannot be denied. The most impressive evidence of this early occupation was unearthed at the site of Mehrgarh between 1974 and 1985 (Jarrige, 1984;

Jarrige et al., 1995). The Aceramic Neolithic farmers first occupied the site around 7000 BCE, while the subsequent phases of the Neolithic and Chalcolithic shows a continuation and gradual development in the material culture, culminating to form the Early Harappan phase (3000 BCE). The early phase at Mehrgarh is characterised by the presence of a well-developed lithic (flint) industry, circular and rectangular structures sometimes made of loaf-shaped mud bricks, terracotta female figurines and human burials. Pottery appeared first in the Neolithic around 6500 BCE and copper during the Chalcolithic around 4500 BC. A number of local pre-Harappan Chalcolithic cultures such as the Hakra, Kot Diji, Amri, Kuli, Nal, and Ahar followed and all of them contributed substantially to the development of the Harappan Civilization.

The regions of Mewar and the Mid Ganga basin appear to have witnessed the process of domestication and formation of village life independently in the 6th millennium BCE (Shinde et al. 2004 and Tiwari 2002-03). The Mesolithic site of Bagor in Mewar has produced evidence of early animal domestication and semi-permanent sedentary occupation of a complex village organisation that spread into various parts of Rajasthan and Gujarat (Shinde, 2000; 2002 and Shinde et al, 2004). Plant remains were not recovered and studied from this site. The site of Lahuradeva in the Mid Ganga basin has also provided similar evidence (Tewari, 2002-03). The works at the site of Padri (Saurashtra), Nagwada and Loteshwar (North Gujarat) and Balathal and Gilund in the Mewar region of Rajasthan have provided evidence of early village life going back to the middle of 4th millennium BC (Shinde 1998; Sonawane and Ajithprasad 1994).

The early phase is characterised by small but increasingly complex communities which had already realized the favourable factors of a sedentary lifestyle along with a mixed economy based on agriculture, animal husbandry and some amount of hunting, gathering and fishing where possible. The basic technological breakthrough in ceramic, smelting and melting of metals and artefacts manufactured in the form of tools, utensils, ornaments, construction techniques, etc. had its origin and initial evolution in this early phase of socio-economic complexity. These technologies were developed and introduced gradually by the Neolithic/Chalcolithic folks within the subcontinent.

The developed (mature) Chalcolithic phase is marked by the presence of specialized craft production, use of advanced technologies, a class-structured society, and economic prosperity reflected in its material culture and the establishment of long distance trade networks. It is in this developed phase that one can see an overall development in pyro and non-pyro technologies. Excavations carried out at sites like Inamgaon, Daimabad in the Deccan, Navdatoli, Eran and Nagda in Central India, Balathal, Gilund, Ojiyana in Mewar, Ganeshwar, Jodhpura in Western Rajasthan and Lahuradeva in the Mid Ganga plain, and a number of Copper Hoard culture sites in north India have thrown light on the various technologies in use during this period and these sites have also produced positive evidence in respect to the presence of craft specialization. There is evidence of a chiefdom society at a number of sites including Balathal (Sinha, 1998), Gilund and Inamgaon (Dhavalikar et al., 1988; Shinde, 1991), while evidence of religious beliefs including fire worship, male and

female terracotta figurines, bull figurines and burial of the dead have been documented at a number of Chalcolithic sites in the Deccan (Dhavalikar, 1998).

The Neolithic/Chalcolithic phase in the Indian subcontinent was characterized by sedentary settlements, domesticated plants and animals, a ground and chipped stone industry with a microlithic component, some use of copper technology, hand-made and wheel-made plain and painted pottery and also Black-and-Red ware, a mixed subsistence based on farming, stock raising and limited hunting and gathering (Agrawal and Kharakwal 2003). A number of Chalcolithic cultural sub-traditions have been identified and though most of these share a number of common features, they produced distinct painted pottery allowing differentiation. Most of the sites in the region seem to be first occupied in the developed Chalcolithic phase dated between 2500 BCE and 1000 BCE, the most prosperous phase of the Chalcolithic culture. Excavations in central and south India suggests that village life originated at a few selected sites and subsequently, after attaining prosperity and increased population, they spread across the subcontinent. Evidence from Mewar indicates that the developed Chalcolithic phase in this region ultimately culminated in proto-urbanization, which was parallel and contemporary to the Harappans but independent of it. In order to acquire required raw material and finished goods they traded with different regions including the Harappans.

By 1500BCE to 1000 BCE most of the Chalcolithic settlements from the Indian subcontinent were deserted and only a few sites managed to survive until 700 BCE in the southern Deccan region, particularly the Bhima River basin where the important site of Inamgaon is located (Shinde, 1989). The data from the Late Chalcolithic phase from many parts of India clearly indicates a decline in the material and technological culture and lifestyle. Circular huts replaced the large spacious houses of the earlier phase and the classical Chalcolithic painted pottery degenerated in quality. The dependence of the people on agriculture for their subsistence changed to a more semi-nomadic mode with increased dependence on sheep/goat pastoralism. The reason for this decline is not yet properly understood, but the onset of arid climatic conditions may have been responsible.

Pyro Chalcolithic Crafts and Technologies

Chalcolithic technologies can be divided into two broad categories, pyro and non-pyro, where pyro refers to industries that involve the use of fire. There is ample evidence in the Chalcolithic levels for the use of pyro-technologies (pottery, bricks, terracotta, lime, paste and faience, metallurgy including copper and gold/silver, etc.).

Pottery manufacturing: The earliest evidence of pottery manufacture comes from the site of Mehrgarh in Baluchistan, dated to 6500 BC. One of the characteristic features of the Chalcolithic period is a well-developed ceramic industry, including fine painted, plain and coarse pottery for a variety of purposes. Ahar, an early farming community of Mid Ganga, and Narahan cultures also produced Black-and-Red wares. Pottery manufacturing was an important craft of the Chalcolithic period and all the three techniques (handmade, slow

turned table and fast wheel) were in use simultaneously. Fine pottery was made from fine and pure well levigated clay whereas the coarse variety was made from tempering materials such as fine sand, chopped grass, rice husk, cow or donkey dung, etc. mixed into the fine clay. The fine ware was treated with various shades of red colour slip, and then painted with decorations in black or other dark colours and fired at 750°C. All the colours were made from the naturally occurring haematite rock. Usually the fine wares were fired in closed kilns with long fire chambers at the base, the evidence of which is found at sites like Inamgaon (Dhavalikar et al. 1988), Kaothe (Dhavalikar et al. 1990), Balathal (Shinde, 2000), etc. The Black-and-Red ware was possibly fired in closed kilns. Various geometric and naturalistic patterns were decorated on the upper half of the outer surface of the pottery. In case of wide mouthed pots such as bowls, they were also decorated on the inner surface. The commonest shapes included bowls, *lotas*, carinated wide mouthed spouted pots and small to medium globular pots. Small to medium sized globular pots were used for cooking, whereas large sized ones for storage purposes. A number of sites have produced evidence of pottery manufacturing and one of the best examples is the site of Inamgaon that has terracotta and stone dabbers, antler and bone points, pounders, fragments of haematite for preparing colour, pebbles probably for burnishing, and specifically designed close kilns with fire chambers. A number of sites including Balathal and Gilund in Mewar, Kaothe in the northern Deccan, Navdatoli in central India, etc. have produced convincing evidence of pottery manufacturing (Fig. 2). An analysis of selected sites clearly demonstrates that the locally available clay from riverbeds was used for pottery making (Dasgupta, 2004). Most of the local potters still use technology that is similar to the Chalcolithic period.

Comment: EXPLAIN THIS TERM OR ELSE CHANGE IT

Burnt brick: The earliest evidence of the use of burnt brick for construction comes from the site of Gilund, dated to the beginning of 4th millennium BCE, which was excavated by the authors. This building material was not common in the Chalcolithic period in South Asia. Occasional use of such bricks for construction is found at sites such as Nagda and Eran, where it was used for the construction of fortification walls. At Gilund most of the structures on the southern part, identified as a craft manufacture area, have been made of burnt bricks. The Chalcolithic people at Gilund also introduced the header and stretcher construction method. Similar burnt bricks are being manufactured in the rural parts of India by using the same technique as that of the Chalcolithic.

Terracotta: In the subcontinent terracotta art is associated with settled life. A large number of terracotta objects were manufactured and used by the Chalcolithic people for domestic and religious purposes. The domestic objects included spoons, ladles, ornaments such as beads, bangles, ear-studs, etc. A number of sites have yielded animal figurines such as the bull, tortoise, a variety of birds, human (male and female) figurines and a variety of miscellaneous objects, most of which have been associated with the religious beliefs of the people. These were most probably manufactured locally. These objects were hand-modelled, made of fine clay, sometimes treated with either red or grey slip and fired to a temperature of around 650° C. Sites such as Kayatha and Marmi in central India, where a large number of bull figurines were found, appear to be centres of production (Misra et al., 1993). Inamgaon has yielded a large number of terracotta figurines, both male and female, indicating that it might have been

one of the important regional centres for the manufacture of these figurines. Most of the sites producing the evidence of pottery manufacturing will be ideal ones to study for the terracotta manufacturing techniques. There are ample ethnographic parallels in modern western and eastern parts of the country where such techniques can be studied.

Lime: Chalcolithic house floors, walls and sides and bottoms of silos were plastered with lime, mainly to keep away insects. Although there is evidence of the use of lime in almost every excavated Chalcolithic site, the only site that has produced the evidence of manufacturing it is Inamgaon, where lime-making was a flourishing industry.

Paste and Faience: From the beginning of the Chalcolithic phase, paste and faience beads formed an important part of their jewellery, as is evident at Mehrgarh, Padri, Prabhas Patan, Balathal, Gilund, etc. The paste beads were made from the white quartz powder by adding alumina, sodium and potassium as flux. Faience was made from ground quartz sintered with glassy bonding material made with alkalis and lime and glazed with bright coloured alkaline and lime glazes containing metal oxides. Both were then fired in small kilns, however such kilns for firing paste beads have not been identified at any Chalcolithic site. Also there is a need to identify workshops and tools used in the manufacture this craft. This craft has not been properly studied and therefore we have not yet understood various aspects such as the exact nature and source of raw materials, manufacturing process, firing techniques, etc. The Harappan site of Kuntasi in Saurashtra, Gujarat, contemporary to the Chalcolithic period, has produced a large, circular fireplace, which is identified as a paste-bead firing kiln (Shinde 2004). A large circular kiln, built in a pit and provided with a thick layer of sand all around, called a sand bath, contains a large pot, which may have been used as a container for the beads to be fired. The Chalcolithic craftsmen might have used a similar kind of kiln for firing purposes.

Copper metallurgy: The technological development of copper metallurgy in the subcontinent has been well documented (Agrawal 1971 and 2000). Chalcolithic people were responsible for the origin and development of this metallurgy, the evidence for which is found from the middle of the fifth millennium BCE. The source of Khetri Copper belt of Rajasthan may have provided the required raw material to the people of the Chalcolithic and subsequent cultures. This is the richest source of copper available in the subcontinent even today. Other locally available chalcopyrite nodules may also have been exploited for this metal. The smelting activity was apparently done remotely from settlements. As these sites have not been subjected to systematic research, adequate data on the mining of copper ore and the techniques of extraction of metal is not available. There is a possibility of the use of antler picks, the evidence of which is found at a number of Chalcolithic sites in Rajasthan and Central India, for mining the ore of copper from the mines. A number of tribal communities in Central India are still engaged in the mining and smelting of copper ore and manufacture of objects by using primitive techniques which are believed to be similar to the ones used during the Chalcolithic period. A study and documentation of their techniques would enable reconstruction of the technologies of the Chalcolithic period.

Extracted metal was transported to the habitation sites where it was converted either by casting in mould or cold hammer techniques into various artefacts, including tools and ornaments. Copper objects recovered from the site of Kayatha in Central India were found to be made by the use of casting technology (Ansari and Dhavalikar, 1974), whereas those found at all other Chalcolithic sites were made by cold hammering techniques. The tool types found at numerous excavated sites include flat axes, spearheads, swords, arrowheads, chisels, points, punches, nails, etc. and ornaments such as beads, pendants, bangles, rings, etc. Some of the Chalcolithic communities located near the source of copper at Khetri, particularly in Ganeshwar-Jodhpura, were actively engaged in manufacturing various copper objects for consumption and trade. In all probability, they supplied copper ingots and copper objects to the Harappans as well as to the Chalcolithic people of other traditions. It also seems that some tools such as leaf-shaped arrowheads, chisels and nails were made here for the Harappans. In the Ganga basin and parts of Northern Rajasthan a large number of heavy copper implements such as anthropomorphs, harpoons, swords, etc. have been found in many sites. They have been associated with the Copper Hoard/OCP culture dated to the beginning of second millennium BCE. Their function and manufacturing technique is not known.

Sites such as Ahar and Balathal in the Mewar, Inamgaon and Daimabad in the Deccan, Padri in Gujarat, Ganeshwar and Jodhapura in Rajasthan have evidence of manufacturing copper objects such as crucibles and small furnaces (Fig. 3) for heating and melting. Some of the tribal people of the Bastar region still practice primitive technologies and need to be subjected to detailed studies with a view to generating data on reconstructing Chalcolithic manufacturing technology. At the site of Ahar in Mewar, iron was found in the Chalcolithic phase dated to 1400 BCE. This is very significant evidence which will facilitate the understanding of the origins of iron technology in the subcontinent, because it is plausible that the copper technology developed by the Chalcolithic people served as the basis for the development of iron technology in India. The site of Ahar deserves to be studied in great details from this point of view.

Gold: A small number of gold ornaments have been reported from selected sites, including mostly beads and pendants made by foil techniques. In all probability the Chalcolithic people acquired gold from Hatti mines near Gulbarga in Karnataka. A small circular furnace found in one of the structures at Inamgaon and a pair of tongs may have been connected with gold ornament manufacture activity (Dhavalikar et al., 1988). There is no convincing evidence of the use and manufacture of silver objects in the Chalcolithic levels in the subcontinent.

Non-Pyro Chalcolithic Crafts and Technologies

Architecture: The Chalcolithic period in general is characterised by simple to complex structures made of mud, wattle and daub, stones, mud bricks or burnt bricks. In addition, multi-room complexes, public architecture and well-planned settlements were also built. Architecture of different categories such as dwellings for common and elite classes, workshops for various craft manufacturing, and public buildings such as fortifications,

granaries, irrigation canals, jetties, religious structures, etc., have been identified at a number of excavated Chalcolithic sites.

The simple dwelling structures included subterranean or over-ground circular huts and single or double-room square and rectangular units. These structures had low mud walls and wattle-and-daub construction over them (Sankalia, 1974). Most of the structures had well made plastered floors and walls, while cooking and storage areas exist inside. There is no direct evidence for the manufacture of these architectural features in the archaeological context. Similar types of structures are being built till today and a study of these structures has yielded ample information about their construction method (Shinde, 1991a).

The structural complexes excavated at a number of sites, including Mehrgarh, Balathal and Gilund were made of mud bricks or stone, depending upon the availability of raw material in the vicinity. These complexes had stone foundations and mud brick walls. Some of the complexes excavated have over a dozen rooms of different sizes, and on the basis of contents it was noticed that each room of the complex served different function including dwelling, storage, craft manufacture, cooking, etc. In addition, multi-room complexes, public architecture such as fortifications and granaries and well-planned settlements are also found. The site of Balathal had a stone fortification wall, whereas Gilund, Eran and Nagda had mud brick fortification walls. Mud walls fortified Inamgaon and Daimabad. The stones and mud bricks were set in mud mortar, whereas the mud walls contained stones at places for strengthening purposes. These walls, broad at the base and narrow towards the top, have survived to a considerable thickness. One of the aims of this research will be to study their exact function and method of construction. A surrounding ditch also protected sites like Inamgaon and Nagda and this technique introduced by the Chalcolithic people continued through the Early Historic into later periods in India.

Granaries have been identified at Gilund and Inamgaon. The one found at Gilund is a large 15 m X 12 m structure made of parallels walls of mud-bricks (Shinde and Possehl, 2005) (Fig. 4). Five parallel walls placed at a distance of 1.5 m from each other have been plastered from inner and outer faces. It is hypothesized that the place between the two walls was used for storage purposes. The structure identified as a granary at Inamgaon is a large square mud structure containing half a dozen circular platforms and the same number of cylindrical underground pits (Dhavalikar, et al., 1988). The top of the mud platforms and sides and bottoms of cylindrical pits (silo) were plastered with cow dung and lime. The platforms were used for supporting storage bins whereas the underground pits were used as storage containers. There are ethnographic parallels for both and hence it is not difficult to study their methods of construction in order to identify the tools used for making them. A rectangular platform found by the side of the river Ghod close to Inamgaon has been identified as a jetty. The site of Balathal has produced unique evidence of a public structure identified as a fortified enclosure. This roughly rectangular structure measuring 30 m (E-W) by 20 m (N-S) is the only structure of its kind in the Chalcolithic levels of the subcontinent (Shinde, 2000) (Fig. 5). It is located in the middle of the settlement with massive walls of stone set in mud

mortar and bastions on two corners. The average thickness of the wall is 5 m on top and 7.5 m at the base.

Flint-knapping: One of the characteristic features of the Chalcolithic subcontinent is the presence of a blade industry right from the beginning of this phase. The fine slender and parallel-sided blades can be detached from the core by applying either the punch or pressure technique. The most common materials used by the Chalcolithic were chalcedony and chert, with occasional use of quartz and jasper. These are commonly found almost all over the subcontinent and possess a concoidal (vertical break) fracture property, a basic requirement in the manufacture of blade tools. The raw stones are first dressed into desired form by removing flakes with a stone hammer and while preparing the core one or more ridges are created along the longitudinal axis. There are a number of specimens showing parallel flutings which are the negative flake scares of the blades that were already struck off. These parallel-sided blades then were converted into various tool types such as blunted back, crescents, trapeze, points, etc. by retouching them. These blade tools were either used with bare hands or made into composite tools such as sickles. On the basis of the even distribution of debitage and blades at Navdatoli, it has been suggested that every household prepared its own tools (Sankalia et al., 1974). At the site of Inamgaon a house of a flint-knapper has been identified, which contained in it more than a hundred crescents and large number of debitage around a stone, which may have been used as an anvil (Dhavalikar et al., 1988). Tools such as hammer stones, fabricators, antler and copper punches, etc. found at many sites may have been used for making blade tools.

Lapidary: One of the most important industries throughout the Chalcolithic period in the subcontinent was the manufacture of beads of semi-precious stones such as agate, carnelian, jasper, chert, steatite and serpentine. The technique of manufacture of bead rough-outs was not very different from that of manufacturing the core for blade tools. Similar types of tools were used in both. Some of the sites also have sand stone slabs with parallel groove marks and these were used as bead polishers. The grooves appear to have resulted from polishing the bead rough-outs. The raw materials required for bead making when not locally available were sometimes acquired from a long distance via trade networks. In the Khambat region of Gujarat, the stone bead industry is still important where modern as well as traditional methods have been employed. A number of scholars have studied these techniques and systematically documented them (Kenoyer et al. 1991). This source will be of great help in the reconstruction of the bead making technology.

Polished stone tools: Chalcolithic sites in the Deccan and elsewhere have a considerable number of polished stone tools. The most common material used is dolerite, which is found all over the Deccan region. The tools consist of axes and adzes and in both cases grinding and polishing obtained the cutting edge. A large number of polished stone tools have been recovered from Inamgaon, but there is no evidence of manufacturing at the site. The manufacturing technique may have been simple. In the first stage a pebble was converted into a rough-out, which was then polished on the rough stone.

Agriculture: The Chalcolithic people grew a variety of crops, including wheat, barley, rice, a variety of pulses and oil seeds in the fertile black cotton or alluvial soils surrounding most of their settlements. Plough cultivation is inferred in the Chalcolithic levels although there is no direct evidence for the implements. The possibility is that the hard wood of *khair* (*Acaci catechu*) may have been used for making ploughs, which may not be different from the Harappan plough found in the form of a model at the site of Banawali. However, the actual discovery of a ploughshare made of a shoulder bone of cattle at Walki (Pune District, Maharashtra) demonstrates that such ploughs may have been made (Shinde, 1991b). Besides, antler picks and perforated discs referred to as mace heads found at many sites may also have been used for digging purposes (Shinde, 1987).

Hydraulics: Wheat was grown in the Deccan region with the help of artificial irrigation systems developed by the Chalcolithic people. The best evidence of this comes from the site of Inamgaon in the lower Deccan region. The evidence of an irrigation canal, 240 m long and 2.5 m wide and deep was discovered. Parallel to it was constructed an embankment wall of stones set in mud mortar. It was build with a view to preventing the canal from silting up (Dhavalikar et al., 1988). This is the best hydraulic evidence associated with the Chalcolithic in the subcontinent. The site has yielded a number of antler picks, which may have been used for digging this canal. A number of small rivers, particularly tributaries of major rivers, may have been dammed for irrigation purposes. We have no clue whether or not the Chalcolithic people dug wells and water tanks within the site.

Shell industry: The Chalcolithic people made bangles and beads using conch or chank shells. The nearest source for this variety of shell was Saurashtra and the Harappan trade networks distributed it. The outer surface of the shell was removed and then it was cut in a circular manner with the middle stem called columella thrown away. A number of sites have produced evidence in the form of finished and unfinished products indicating its local production. Copper knives and stone blade tools found at many excavated sites may have been employed for manufacture (cutting). Shell bangle manufacturing is one of the flourishing industries in West Bengal, where modern and traditional technologies are employed.

Bone/antler/wood: Almost every Chalcolithic site has evidence of bone and antler tools, indicating local production at almost every site, except for temporary settlements such as farmsteads or camps. A few beads made of bone have also been found. Bone and antler tools such as chisels, knives, points, awls, punches, picks, etc. were made either from whole long bones or from the splinters. Simple technique such as chiselling and grinding may have been practiced for the production of these tools. Tools such as copper chisels, parallel-sided stone blade and grinding stones may have been used in the manufacturing of implements of bone and antler. Of course the Chalcolithic people may also have used a lot of wooden implements which have not survived over such a long period.

Stone: Locally available stones were used for manufacturing objects such as rubbers, mullers, sling balls, hammers and saddle querns. By constant use the querns become hollow and

curved and are hence referred to as saddle querns. Grinding stones come in different shapes: round, oblong, rectangular and so on. Stone balls or sling stones, which have been found in large quantities, may have been used for hunting birds and small games. These objects of day-to-day use may have been manufactured locally at every site. None of the sites has yielded any evidence of the manufacturing technique.

Ivory: Some to the Chalcolithic sites have yielded small disc beads of ivory. Since only small quantities of beads were found, no effort has been made so far in reconstructing technique used for manufacturing them. Ivory chunks may have been acquired from Gujarat and southern India and the production of beads may have been local.

Textile: The site of Balathal in Mewar region of Rajasthan has produced the physical remains of woven cloth, indicating that the Chalcolithic people developed this art. Almost every Chalcolithic site has produced a large number of perforated discs, identified as spindle whorls. It is surmised that they were used in spinning thread, most probably of cotton. No evidence of cotton has been reported from any Chalcolithic site, but it was very much cultivated by the Harappans, who were contemporary to the Chalcolithic at some point. Traditional weaving looms are found in many parts of western India and they could provide ample evidence for reconstructing Chalcolithic technique.

In addition to the above-mentioned crafts there may also have existed technologies for making color and medicine, evidence for which is yet to be found.

Concluding Remarks

Neolithic/Chalcolithic cultures flourished almost all over the Indian subcontinent mainly in the proximity of fertile arable land. This phase bridges the gap between the Stone Age and Early Historical age and provides an important clue to the missing link in the history of mankind in the subcontinent. Systematic research carried out in various parts of the subcontinent on the Chalcolithic phase has enabled reconstruction of social-economic and religious life of the people of that period. The presence of large-scale manufacturing activities within some of the settlements is a clear indicator of craft specialization and this is considered to be one of the characteristic features of a chiefdom society. The excavations at Inamgaon have produced ample evidence in support of a chief and the chiefdom social organization during the Chalcolithic times. The evidence for the presence of public buildings, strong hinterland trade, etc. corroborates the presence of a chiefdom society during the Chalcolithic times. Many traditions and technologies developed by the Neolithic/Chalcolithic communities continued though the ages and have survived in India even today. Rural India has preserved these traditions and it proves to be a very useful source for the reconstruction of various aspects of the Chalcolithic lifestyle, including technology. A distinct Neolithic/Chalcolithic phase has not yet been identified in a number of countries of the subcontinent, including Sri Lanka, Bangladesh, Nepal, Bhutan and Burma

Ch5

ARCHAEOMETALLURGY IN EASTERN INDIA

BY PRANAB K. CHATTOPADHYAY AND GAUTAM SENGUPTA

Preamble

Metallurgy is one of the earliest branches of Science developed by mankind. To trace this development, an in-depth study is necessary on the material remains of the past with scientific and technological inputs. Archaeometallurgy, therefore, draws upon the expertise of the archaeologist and the metallurgist. This multi-disciplinary branch of science is developing fast with the application of sophisticated instruments and techniques. In the Indian subcontinent a number of research works dealing with metal technology or archaeometallurgy have been published in the last five decades. Among them, N. R. Banerjee's work on *Iron Age in India* (1965), K. T. M. Hegde's *Technical studies on Chalcolithic Copper Metallurgy* (1965), D. P. Agrawal's *Copper-Bronze Age in India* (1971) and *Ancient Metal Technology of South Asia* (2000), H. C. Bhardwaj's work on various *Aspects of Ancient Indian Technology* (1979), A. K. Biswas' *Minerals and Metals of Ancient India* (1996), S. Srinivasan's studies on *South Indian Metal Icons* (1999, 2004), B. Prakash's *Ferrous Metallurgy in Ancient India* (2001), R. Balasubramaniam's Studies on *Delhi Iron Pillar: New Insights* (2002) and V. Tripathi's studies on *The Age of Iron in South Asia* (2001) are significant. The recently published book, edited by A. K. Biswas (2005) on *Science in Archaeology and Archaeo-materials* is a new addition to the history of science and technology.

One may also mention a project under the General Editorship of D. P. Chattopadhyaya which includes some remarkable studies pertaining to archaeometallurgy. Reference may be made to the contributions of D. P. Agrawal (1999) on Chalcolithic Cultures and Technology, V. Tripathi (1999) on Early Iron Technology and its Socio-economic impact, P. Singh (1999) on The Rise of Cultures in Eastern India, C. V. Sundaram *et al* (1999) on History of Metallurgy in India, K.V. Soundara Rajan (1999) on the Various Aspects of Copper and its Alloys and their impact on Indian Religion and Culture. A. Soundara (1999) also contributed to the study of Indian Megaliths and the Iron Technology. A preliminary work on the Archaeometallurgy of Bihar, Jharkhand and West Bengal has been made by Chattopadhyay (2004).

The present study aims at giving an overview of archaeometallurgy of the lesser known areas in the Eastern part of India. The definition of Eastern India for the present paper comprises of the following states of the Republic of India: Bihar, Jharkhand, Orissa and West Bengal.

Beginning of Metallurgy: Protohistoric Period

Eastern India has witnessed the gradual developments in lithic technology. More importantly this part of the country is very rich in mineral resources. Ore-minerals such as copper, iron, tin, lead, zinc, silver and gold is of paramount importance. Gold nuggets have to been found from the streambeds of the rivers. Gold flakes mixed with sand are known from the upper course of the rivers. The local tribal people were familiar with the methods of separation of the gold flakes. Gold panning was done twice in a year, once after the rainy season and again during the winter. The washing was carried out in rectangular vats in which gold particles were separated from heavier minerals. There is every possibility of existence of native copper on the gossans of the copper mines. The existence of these minerals also coincides with prehistoric habitat zones. The environment in the wooded plateau region of Chhotanagpur and its fringe areas in Orissa, Jharkhand and West Bengal, perhaps, witnessed independent origins of metallurgy. Some meaningful works have been initiated to understand the origin and development of metal technology in this part of India. The typologies of preliminary metal objects clearly indicate the development from their lithic counterparts.

Until now there has been no coherent study of the development of metallurgy of the Pre-modern period in these four Eastern Indian states. It may not be possible to be very specific about the origin of metallurgy in this part of the country, but with the support of recent archaeological findings, and scientific methods, an in-depth study may be initiated to develop a better understanding of the metallurgical tradition of the region.

Jharkhand: In purely archaeological terms, metallurgy was initiated in this part of the country in Neolithic-Chalcolithic transitional phase, some times around 2000 BC. It may be argued that the metal manufacturing technique in this region developed either due to a process of independent origin or through diffusion. According to D. P. Agrawal (1971:196-97), early human beings of the wooded plateau of Singhbhum copper belt might have independently discovered the copper metallurgy in Jharkhand.

Bihar: The earliest evidence of copper is known from Senuwar (Singh 2004). This is supported by two C14 dates of 1770$\pm$120 BC and 1500$\pm$110 BC. It has been inferred that the copper smiths of Senuwar had definitely started smelting copper ores by 1950 BC. This is the earliest date for metal objects of Eastern India. This may be equated with the late phase of Harappan culture. A trace element study on the copper objects established that they were not imported from Araballi of Rajasthan or Harappan sites. Instead, they had closer similarities with those of the Singhbhum mines. A solitary piece of lead pin has been discovered from the site. In the late Chalcolithic phase, copper objects were made of bronze- an alloy of copper and tin. A number of Chalcolithic settlements are known in the Ganga Valley. At Chirand, period IA has been identified as metal free, whereas period IB indicated the presence of some copper objects including point, fishhook, rod, bangle etc. At Maner, not a single metal object has been found from period I. But next to this level, copper objects of this period include a fishhook; three points, three bangles, etc.

Orissa: The first discovered site associated with the earliest evidence of metal objects from Orissa is Golbai Sasan. Sinha (1992-93) discovered copper artifacts and crucibles for smelting copper from period IIA whose tentative dating was 1400-900 BC. From period IIB, designated as Ferrochalcolithic, a crude iron Celt was recovered.

West Bengal: The metallurgical activities related to copper metallurgy from West Bengal need to be reviewed. The copper bearing level at Pandurajar Dhibi has been dated to 1090±110 BC (PRL-1184). The earliest evidence of bronze casting of Eastern India is also known from Pandurajar Dhibi (Fig. 1). From trench 7A, iron tools double axe, terracotta mother goddess, hammered gold piece bearing minute parallel scratches and a bronze fish containing about 95.5% copper have been found (Biswas 1996: 173). Low amounts of tin (about 10.0%) has been noticed in ornaments and other objects, which might be due to the presence of tin in copper minerals or low tin-bronze making technology. Whatever might be the case, people knew the utility of tin in alloying but their knowledge about proper composition was perhaps not adequate. There is no evidence of arsenic being used as an alloying element. Similar presence of copper is known from Mangalkot and Pakhanna.

The earliest evidence of iron has been noted from the period IIB (Ferrochalcolithic level) of Pandurajar Dhibi. Iron smelting activities have been noted from the site where tuyers entrapped with slag have been discovered. The iron bearing level of this site has been dated (C14) to 1090±110 BC (KN 3755). From Pakhanna, furnace remains along with entrapped paddy husks have been discovered. Remains of a smithy were recovered during the excavation of 2002-03. At the lowest level, a terracotta basin for water storage has also been found along with hearth, charcoal, ash, iron implements etc. The excavations conducted in the state clearly indicate that iron manufacturing was practiced at various sites. The smiths definitely were the part and parcel of the village and supplied farming tools like ploughshares and sickles to the farmers; axes and chisels to the carpenters; spear, swords and arrowheads for the purposes of hunting or defence. The easy manufacturing technique of iron and the local lateritic and limonitic iron ores changed the socio-economic status of the smiths.

With the discovery of iron technology, a significant advancement took place. Iron manufacturing and its impact on the society were quite considerable. Excavations at Bahiri revealed iron slag on the natural soil at 900 BC level (Chakrabarti and Hasan 1982). The carburisation was unknown at the first stage. Iron with slag inclusions or wrought iron was used. By experimentation they discovered carburization, which was achieved while heating and forging the metal in a smithy. The earliest example of carburisation has been detected in a knife found at Hatikra, West Bengal, dating around c. 1000 BC. This object clearly indicates that carburisation was not accidental because the finished product had to be heated in a furnace for further carburisation after the completion of the forging process. The evidence of Widmannstätten pattern in the microstructure also supports this argument. Use of quenching and tempering has been identified in a sickle, discovered in the excavation at Pandurajar Dhibi, dated c. 3rd century BC.

Metal crafts: Early Historic Period:

In this context, one may mention the Copper hoard objects of this region. The origin and the subsequent development of copper objects have not been satisfactorily explained so far. It has been presumed by some scholars that the tradition began in the Chalcolithic period. Yule and Horstmann (1985) have spoken about OCP and Copper hoard being contemporaneous on the one hand and of Copper hoard and black-and-red ware on the other. The implied view in the formulation is that the Copper hoards of Jharkhand, Orissa and West Bengal are associated with the black-and-red ware complex of the Chalcolithic phase. Studies have revealed that the copper-bronze objects of Dihor bear close similarity with the copper hoard objects of Akhuldoba, both the sites being located in West Bengal. The tool types in Copper hoards of Jharkhand, Orissa and West Bengal clearly suggest that they do not belong to single period; they not only began prior to the Early Historic period but continued till early Medieval period.

The excavated materials of this phase throughout Bihar, Jharkhand, Orissa and West Bengal have widely revealed the advancement of technology in this period. Punch marked silver and cast copper coins have been widely discovered in this region. It is interesting to note that earliest evidence of brass was also identified at Senuwar; an antimony rod of the Kushana period revealed that it was made of brass with 36.2% zinc. In Pandabasthal wide use of metallic objects are noted.

Sisupalgarh of Orissa, the ancient city of Tosali, has also revealed copper, iron, and lead objects along with copper, silver, gold and lead coins and coin moulds (Lal 1949). A large number of Iron Age – Early Historic sites have been discovered in the middle Mahanadi valley of Orissa (Behera 2002-2003). The recent exploration and excavations in Orissa by the team members of the Sambalpur University have brought to light important information. The iron objects recovered from Badmal were studied recently and indicate that the ancient settlers of the site used to procure iron from two different sources; either in the form of ore or as objects of trade. Often it is mentioned that the smiths of the Iron Age in the Indian subcontinent applied ‘layering forging techniques’. This has been established through the archaeometallurgical studies of iron objects of Badmal, Orissa (Behera and Chattopadhyay 2005).

From Lalitagiri Buddhist relics made of gold and silver along with coins, silver ring and iron objects have been found. This is the only site in Eastern India in which 200 gram silver slags were recovered (Chauley, 2000 p.450).

With the invention of iron manufacturing, significant change took place in the social and economic life of the people. A terracotta plaque (Fig. 2) has been discovered from Chandraketugarh, and preserved in the State Archaeological Museum, West Bengal. The plaque shows three farmers reaping paddy with highly developed iron sickles of larger size, signifying a developed agricultural practice in the early historic period. Besides sickles, ploughshares, hoe, axe, chisels etc were also used.

Metal crafts: Late Historic Period

The major impact of bronze on the late historic period in Eastern India had been start of production of large numbers of bronze sculptures of high artistic skills. Some of the sites, like Nalanda, Kurkihar, Jhewari have yielded hundreds of bronze sculpture.

From the the Mauryan period onwards, manufacturing of metal images began in this part of the country. Gold plaques found at Patna Fort are datable to the Mauryan period. There is reference for a gold repousse figure from a burial mound of Lauria Nandangarh dated around 6th century BC and also of the fragmentary lead relief discovered at Bulandibagh, Patna (Agrawala, 1977: 48-69). Art historians have made significant studies on the images of Eastern India but our knowledge of their manufacturing processes is still in its infancy. One must study in detail the sources of metal and their casting techniques. Hoards from Salar and Tapan (Dist. West Dinajpur) are under metallographic investigation by a team consisting of scholars from the Saha Institute of Nuclear Physics, National Test House, State Archaeological Museum and Centre for Archaeological Studies and Training, Eastern India.

Metal crafts: Medieval Period

Specific, contextualised materials from this period are few and far between. However, a large number of metal-using sites have come up during this period. These centres produced metal objects of everyday use. An exceptional category such objects is the cannon. In Eastern India a number of cannons still survive as evidence of this unique medieval technology. The cannon may be grouped into three types according to their constituents: forged wrought iron, cast iron and brass or bronze. Cannons in India may also be divided into groups pertaining to their size and use. *Ain-I Akbari* (R1993: 119) refers to the names of cannons like '*Gajnāls*', which could be easily carried by a single elephant; '*Narnāls*' is a device, which could be carried by a single man. The most popular cannon of West Bengal is Dal Mardan or Dal Madal presently located at Bishnupur, District Bankura. This cannon has been thoroughly studied by Balasubramaniam *et al* (2005). This study is the most documented guideline for application of Archaeometallurgical methodologies to reveal the technological details of Indian cannons. From literary references, some information gathered on the classification of bronze and other copper objects of the medieval period. Varieties of forms in copper alloys are known. Some ideas on sixteenth century copper alloys may be available in *Ain-I Akbari* (Abu 'L- Fazl Allami R. 1993). A brass cannon of Krishna Chandra Ray of c. 17th century in Victoria Memorial Hall, collection is shown in Fig. 4.

Pre-Industrial traditions

Ethno-archaeological studies provide insights into the traditional bell metal and brass making technologies adopted by the Kanasaris of Eastern India. The Kāngsakāras or Kānsāris are

traditional craftsmen involved in the manufacturing of bronze or bell metal in West Bengal. The Dokra craft continues even now in Bihar, Jharkhand, West Bengal and Orissa.

Bihar, Orissa and Jharkhand are also important areas of pre-industrial iron smelting in India. Iron smelting practices of Agarias have been described by Ball (1880), Joshi (1975), etc. Recent studies on traditional iron-making have already drawn considerable interest. Mohanta (et al. 2003) have discovered charcoal making furnaces and studied Pre-industrial iron smelting in Maurbhanj.

There is enough scope still left for a re-evaluation of traditional techniques in this part of the country. However, systematic explorations backed by a series of test excavations conducted during the last decade have brought to light a number of pre-industrial sites.

Ch 6
Iron Technology and its Legacy in India

By Vibha Tripathi

Iron technology in India has a long history going back to the 2nd millennium BCE. The saliency of high quality iron and steel being produced in India was acknowledged by the ancient world Civilizations. Ancient Indian iron workers exhibited exceptional ingenuity, evident in their innovations in the manufacturing of sharp edged objects like daggers and swords. Records left behind by foreign historians like Herodotus (5th century BCE) testimony to the use of iron-tipped arrows by the fighting armies in the battle of *Thermopylae.* Almost at this very juncture Ktesias the Greek ambassador gratefully acknowledged the gift of Indian swords that he received in the Persian Court made to him by the king and his mother. Arrian, another authority of ancient times mentions the import of Indian steel to Abyssinian port. Thus, it is clear that Indian iron and steel was exported to different parts of Greco-Roman world since ancient times. The famous wootz or Damascus steel was a much-acclaimed commercial commodity all over the world till the pre-modem period.

By the early centuries of the common era Indian iron workers had developed sufficient engineering skill to produce even seven ton victory pillars such as the Delhi iron pillar, referred to as a 'rust-less wonder' by T R. Anantraman, an eminent modern metallurgist. The process continued till much later as evidenced by the massive beams once used in Sun Temple at Konark (9th -10th century AD) and the colossal pillar at Dhar (11th century A.D.) During the medieval times the emphasis shifted more towards the manufacturing of weapons such as guns and cannons. The Moghuls displayed ingenuity in cannon making. Many of these masterpieces have survived the vagaries of time.

During pre-modern times,the Dutch imported ship-loads of iron from India. On their arrival in India even the British rated Indian iron much higher and considered it more appropriate than iron produced by their own units for constructing bridges etc. An important example is the famous 'tubular bridge' built in the early parts of the 19th century across the Menai Straits in the United Kingdom. It is categorically stated "...its (iron's) superiority is so marked, that at the time when the Britannia tubular bridge across the Menai Straits was under construction preference was given to the use of iron produced in India" (T.H.D. La Touché, 1918). It has been recorded that 50 tonnes of Indian steel have been used in construction of the famous London Bridge. The swords made in India were prized all were the world. The sword of Tipu Sultan has become a legend. Despite such a glorious past of iron technology in India, several of the writings dealing with the history of iron metallurgy do not have even a word about ancient India's crucial contributions. It is important to write a comprehensive history of iron technology in India covering all its aspects.

The history of iron technology of Mesopotamia, Greco-Roman world, Africa, China etc. are fairly well documented and hence better known to students of history. However, the Indian contributions to the field of metallurgy need to be explored and given due place in the

global perspective of history of sciences and technology. This book is a modest attempt in this regard.

First, a section has been devoted to situate the issue of the emergence of iron in the ancient world in order to locate Indian iron in that perspective. It is in this light that the beginning of iron in India has been examined. Several scholars like Gordon (1958) and Wheeler (1958) placed the beginning of iron in India between 600 BCE and 500 BCE. Its emergence was attributed to foreign sources like the Greeks. Neogi (1914) and M.N. Banerji (1929) relying primarily on the literary evidence argued that the Rigvedic Aryas were conversant with iron technology and used iron for a variety of purposes. The issue of introduction of iron had one more angle, i.e. the technological or metallurgical. Metallurgists like Forbes (1950) strongly advocated that iron technology is too complex to be learnt independently. It had to be learnt and perfected under the guidance of skilled artisans. This assumption along with the knowledge of iron to Rigvedic folk perpetuated the belief of diffusion of iron from some common source.

Lallanji Gopal (1961) synthesized the existing data and came to the conclusion that iron was introduced in India during the Later Vedic times. The word *'ayas'* in Rigveda, according to Gopal stood for metal in general, not for iron. This interpretation of the word *'ayas'* at the earliest stage is significant indeed to the issue of introduction of iron in India. We would briefly discuss the issue of diffusion of iron technology in India.

The Diffusion of Technology:

Philological evidence suggests similarities between Indo-European languages and Sanskrit, and between the Iranian sacred text Avesta and the Rigveda. Inscriptional evidence such as the Boghaz Keui (dated 1365 BCE, a treaty between Hittite king Shubbiluliuma and the Mitanni King Mattiuaza, referring to four Vedic gods) also gave rise to the theory of a common homeland of origins of these cultures. Under such theories iron, which was known to the people of Asia Minor in the 2nd millennium BCE, entered the Indian subcontinent with immigrating groups through Iran. To evaluate this hypothesis, we need to examine in depth a) the evidence of iron in Rigveda and b) the cultural material including iron objects in the Indo-Iranian borders for similarities that followed the theorized intrusions by the immigrants (commonly referred to as "Aryans").

Iron in Rigveda:

The composers of Rigveda call themselves arya - the noble ones - refined or superior people. It is well known that there was some kinship bond between the composers of the Rigveda and Avesta and that the two separated at some point of time. It is important to ascertain whether the aryas who referred to India in the *'sapta saindhav desh'* (the land of seven rivers) had prior knowledge of iron technology such as the use of iron weapons.

The word *'ayas'* occurs several times in Rigveda. The question is whether the Rigvedic ayas stands for iron. Scholars have examined it time and again and various interpretations are available to us today. M.N. Banerji (1927; 1929; 1932), N.R. Banerjee (1965), Gopal (1961), Roy (1984), Tripathi (1994; 1997) etc. have taken a close look and have offered interpretations of the word *ayas*. M.N. Banerji, N.R. Banerjee and S.N. Roy have come to the

conclusion that the Rgvedic *ayas* stands for iron. Therefore, assuming the origin of Rigveda outside India, they conclude that iron arrived in India with Aryan migrating tribes. On the other hand, Gopal and the present author argue that in the initial stage the term *'ayas'* stood for metal in general. The author also feels that adjectives '*Krishna'* or *Shyamayas* and '*Lohita'* were prefixed to *ayas* at a relatively later stage in *Yajurveda samhita* with the emergence of iron to distinguish the 'black metal' (*Krishna ayas* or *Shyama ayas* = iron) from the red metal (*Lohita ayas* = copper). The word *ayas* was a generic term for metal interchangeably used to denote iron or copper till much later date as is clear from literary sources, (see Tripathi 2001). If iron was not known to the Rigvedic Aryans, it would be difficult to maintain to argue that the knowledge of iron came to India with the Aryans.

Archaeological Evidence of Iron on the Borderlands

Archaeologically, the area adjacent to Iranian borderlands, modern Baluchistan (extending over Indo-Iranian plateau) has yielded a large number of cairn burials. Stein (1929) has reported as many as 5100 Cairns. Many of these Cairns have yielded iron objects along with copper-bronze objects and other cultural material along with pottery. Gordon (1950) suggested Iranian connections of Sialk Cementery B and the cairn burials of Baluchistan on the basis of similarities in pottery, burials and metal objects. However, Lamberg-Karlovsky and Humphries (1968) disapprove of the 'Sialk B connections' or Indo-European 'movements to east' towards the cairn burials of Baluchistan because of lack of 'convincing parallels'

A close comparison of chronology, typology and pottery traditions of Baluchi cairns and that of North India tends to lend weight to the contention of Lamberg Karlovsky and Humphries (op. cit.). The burden of archaeological evidence does not favour the diffusion of iron into India from the neighbouring West Asian and Central Asian countries. Firstly, a closer examination of tool typology in Iranian and Afghan sites and those in Sindh and Baluchistan area display little common features with iron objects of mainland India. Secondly, the cultural material corroborates the typological study, i.e. the two areas above appear to be culturally distinct. Thirdly, the chronological considerations go against any notion of diffusion. On Irano-Afghan sites as well as Indian North-west, iron emerges more or less simultaneously viz. around 1100-1000 BCE. It may be noted that recent ^{14}C dates from sites of middle Ganga Plain are much earlier than this.

The Early Iron Age Cultures in India

With this, we come to a difficult juncture of identifying the earliest centers of iron in the country. For a large subcontinent like India it is only too natural that different ecological regions are located in it. For the sake of convenience we have distinguished several iron using cultural zones in it.

Zone A: In this zone, consisting of North-West Frontier provinces of Pakistan and the adjoining parts of Kashmir, a large number of cairn burials have been located. In Baluchistan

as discussed above, at Ziwanri, Take Dap, Moghal Ghundai, Gatti, Zangian etc., (Stein, 1937) and Mockler (1943; 1876). The burials do not conform to any uniform pattern, either in grave goods or in burial practices. They contain a variety of pottery belonging to diverse types. Even chronologically they do not belong to any specific date bracket. Some graves have been opened number of times making it difficult to date them safely. Iron objects like arrowheads, spearheads have been found alongwith ornamental objects of copper, bronze and silver with pottery and bones.

At Pirak in the Kachchi plains of Baluchistan, a unique culture has been discovered, having no parallels in the vicinity (Jarrige and Enault, 1973). A total of 11 layers were discerned there. Iron appears in layer 6 accompanied by a grey coloured pottery which appeared for the first time at this stage. It is roughly datable to 1000 or 900 BCE. In the Gandhara Grave Culture Ghaligai, Katelai, Butkara, Timargarh etc. in Swat Valley (Pakistan) also iron comes from several graves. Here also iron is associated with a new kind of dark grey pottery dated between 1200 BCE and 800/700 BCE. The iron objects consist of arrowheads, spearheads, nails, finger rings and horse cheek bars.

At Burzhom and (recently) Gufkral in Jammu-Kashmir iron has been detected in burials. Recently, the iron yielding levels at Gufkral have been dated to 1900 by ^{14}C. This calls for a serious consideration of scholars about advent of iron in the subcontinent.

Zone B: Away from the hilly tracts of the above zone we come across the iron bearing culture of Doab, i.e. Painted Grey Ware Culture (Tripathi, 1976) which is centred in the valleys of rivers Saraswati, Drisadvati, Ganga and Yamuna. Unlike Zone A, no burials are reported from this culture. Iron comes from regular habitational deposits. This may broadly be dated to the beginning of the 1st millennium BCE, (Tripathi, op.cit.).

Zone C: Over a distance of nearly hundred km., with Kausambi in the West and Rajghat (Distt. Varanasi) in the East, we do not come across any contemporary culture. The intermediary areas of Eastern Uttar Pradesh., Bihar and Bengal are known to be using iron roughly in 15-1000 BCE Recent evidence of early use of iron has been brought forth by excavation at sites like Raja-Nal-Ka-Tila and Malhar in district Chandauli and Sonbhadra in the Vidhyan Plateau quite close to Varanasi and also substantiated now by Jhusi (Allahabad) and Lahuradeva (Sant Kabir Nagar). The Radiocarbon dates of 1500-1400 BCE have pushed back the origin of iron several centuries back. Other important sites of this zone are Narhan, Chirand, Vaisali, Sonpur, Rajgir, Kumrahar, Pandu-Rajar-Dhibi, Mahisdal, Mangalkot etc. Iron in this region is introduced in a chalcolithic milieu.

Zone D: This cultural and ecological zone, consisting of the modern states of Madhya Pradesh and South Eastern Rajasthan and adjacent areas of Maharashtra, is separated from Zone C by the Vindhya-Kaimur and Aravalli ranges. It is rich in ore deposits and has a plethora of the Black-and-Red Ware using chacolithic cultures that precede the iron bearing strata. The key sites of this zone are Eran, Kaytha, Nagda, Prakash, Bahal etc. Eran chalcolithic level is dated to 1300 BCE.

Zone E: The megalithic burials of Vidarbh in Maharashtra have yielded evidence of great significance in connection with iron. Excavations conducted at Takalghat Khapa, Mahurjhari, Junapani, Naikund etc. have yielded iron at the earliest levels. Both habitation sites and burials thereof have been excavated, revealing pottery of a special type and objects like sword, spearhead, arrowhead, ladle, chisel, axe, spike, fish-hook, horse bit, bangle etc. Deo dates it to 800 BCE, (Deo and Jamkhedkar, 1982). But recently much earlier ^{14}C dates have been brought forth pushing the antiquity of Vidarbha megaliths by a couple of centuries. The Naikund excavation has also yielded an iron-smelting furnace, complete with tuyeres, slag and brick tiles used in its manufacture, (Fig.1.A).

Zone F: A large number of megaliths have been brought to light from the peninsular India having several kinds of megalithic burial practices (Sundara, 1975). A typical Black-and-Red ware characterises them. They are rich in iron and are dated to 1100 BCE at Hallur by ^{14}C in its neolithic - megalithic overlap phase. Recent TL dates from Kumaranhalli, Tadkanhalli etc. range between 1440 BCE and 1130 BCE, so far the earliest dates for iron in South India.

It may be added here that in quite a few of the above zones, we have come across ethnological evidence and survival of iron working till recent decades. This reinforces the assumption that there is an un-interrupted tradition of iron making. Metallurgy of iron evolved through such a process. For example, mention may be made here of the Vindhya – Kaimur belt in the Middle Ganga Plain. The early dates of iron from the Vindhyan sites like Malhar, Nal-Ka-Tila and Koldihwa have caught the attention of scholars. They are significant not only for pushing the antiquity of iron by centuries but also for other reasons. Having seen the spatial context of early iron in the Indian subcontinent, we should now take a look at the temporal stages of development of metallurgy in the region.

Development of Metallurgy in Ancient India

Following three developmental stages of metallurgical development may briefly be discerned:

1. Early Iron Age- from the beginning to 7th -6th century BCE
2. Middle Iron Age – 7th – 6th BCE to 2nd -1st century BCE
3. Late Iron Age- 2nd -1st century BCE to the historical period

It may be opportune to take a close look at the state of iron technology at these three stages of metallurgical development.

Early Iron Age

The metallurgical skill was not sufficiently developed at this stage. The wrought iron had plenty of slag inclusions in the matrix of ferrite indicating a solid-state reduction. The iron samples analysed from the site of Hatigra dated 1100-1000 BCE (Ghosh and Chattopadhyay,

1987-88) had observed a widmannstatten structure due to prolonged exposure at a temperature of about 1200 ^{0}C followed by a slow cooling. It is ‘low carbon hypoeutectic steel’. Prakash (personal communication) has thought it is to be hypereutectoid FeC > 0.8% steel.

The furnaces at this stage could hardly generate sufficiently high temperature. Pandurajar Dhibi in district Burdwan (West Bengal) has yielded iron in second phase of chalcolithic culture (De and Chattopadhyay, 1989). Coming from two distinct cultural phases, an evolutionary development in metallurgical skill may be traced on this basis. It may be taken to be a work of coppersmiths who accidentally seem to have picked up the technique of manufacturing iron objects. “The specimen could not be sliced with a hacksaw blade as it is extremely hard and at the same time brittle” (De and Chattopadhyay, op. cit., p.34). Presence of fayalite in large quantity in iron objects suggests the elementary stage of iron metallurgy. No carbide or pearlite structure could be detected on etching. High potassium content indicates use of charcoal as fuel. Thus, it may be suggested that though the iron metallurgy was not well developed yet the method of forging imparted it sufficient strength to make it superior compared to copper objects that were generally being used at this stage. The early metal objects are generally replicas of stone-bone objects that were in vogue since earlier times. This goes to prove an evolution in technology and a transition from one medium to another.

Middle Iron Age

The Northern Black Polished Ware culture takes over the major part of North India by 700/600 BCE. At certain sites it was contemporaneous with late phase of Painted Grey Ware culture on the one hand and the Megalithic cultures on the other. This was a period of consolidation of iron technology with traces of steeling and case hardening or carburisation. A relative increase is recorded in the number and types of iron object. (see Tripathi 2001, Figs. 20-24) There is thus, a qualitative and quantitative improvement in iron objects. We come across more sophisticated weapons like javelins, lances, daggers, blades, elephant goads along with the earlier types. Agiabir, in district Mirzapur, Uttar Pradesh in the Middle Ganga Plain (Singh and Singh 2004, Pt. XX B & A) has yielded a tall lamp stand and swords from a well-stratified deposit of NBPW period along with sizable number of pots and pans of copper-bronze.

Though solid-state reduction of iron remains the technique of iron smelting, there was improvisation in technology, steeling was practiced more frequently. An iron sickle belonging to period III (NBP phase) of Pandurajar Dhibi has been analysed (De and Chattopadhyay, 1989). The microstructure shows non-uniform structure. It is tempered with martensite. It also exhibits retained acicularity at certain places, especially around large patches of ferrite areas. “Electron micrograph obtained at a magnification of 100x clearly represents its tempered martensitic structure”. It may be said that the iron used for fashioning the sickle had been forged at a significantly high temperature that effectively eliminated the slag particles giving the metal a more homogenized structure. Carburization was done during

manufacturing of tools by subsequent heating and forging. Inside the core, the carbon content that is retained is only 0.22%. But the high level of corrosion that took place over the time must have caused depletion of carbon. A much closer analysis seems to be required to ascertain this. Chattopadhyay also suggests quenching and tempering of this specimen. His observation is that the 'carburised iron of the sickle can be safely accepted as a low carbon steel'. Thus it may be deducted that by 4^{th}-3^{rd} century Bengal iron–smiths knew steeling with knowledge of techniques of tempering and quenching.

Some objects from Senuwar in district Rohtas, Chirand, district Saran and Taradih in Bihar and Narhan in U.P. have been analysed recently. In keeping with the trends of this period these analyses also confirm use of mild steel and knowledge of carburisation and lamination techniques, (see Tripathi, 2001, 11, 11a, Figs. 25-A, B). Analysis of various iron objects of the Gangetic Plain suggests that the knowledge of steeling existed around circa 600 BC. Kausambi near Allahabad is rich in iron objects from the NBP ware cultural phase onwards. Agicultural implements, war and hunting objects demonstrate cementation. Similarly, an axe from Jajmau near Kanpur and one from Soron in Gwalior, (M.P.) belonging to 600-300 BCE period shows cementation. An arrowhead from Allahpur in Meerut shows relic carbide. Quenching is rare at this stage. Mention may be made of an axe from Jajmau that is said to be quenched and tempered (Hari Narain et al. 1990-91). Thus there is a definite improvement in metallurgical know how at this stage.

Late Iron Age

Iron technology attained new heights during the Sunga-Kusana and Gupta periods. Khairadih, a site in Ballia district (U.P.) on river Ghaghra has yielded a rich repertoire of iron objects, especially at Sunga-Kusana level. A spearhead that was analyzed shows pearlite and ferrite phase, though slag inclusion is detectable. The microstructure also suggests quenching and tempering; both are rare features. Lamination was also attested to during this stage.

The evidence of Taxila is unique in typological representation as also technological skill. Hadfield (1913-14, Pp.203-204) admired the skill of the smiths "…evidently the Indians in this locality and at this period quite deliberately made high carbon steel". Some of the artifacts contained 1.3% to 1.23% carbon, falling in the category of high carbon steel. A consistent development in metallurgy of iron is discernible here. This phase of Taxila extends from the middle to well into the late stage of our periodization.

The techniques developed further to the highest degree of sophistication under the state patronage in the Gupta period, (3^{rd} – 4^{th} century AD to 5^{th} - 6^{th} century AD). The iron metallurgy culminates with production of massive structures like Mehrauli Iron Pillar at Delhi. Taxila has yielded rich repertoire including some armour grade weapons in the opening centuries of Christian era. Sisupalgah (a Gupta period site) yielded a caltrop, a weapon to be used in the battlefield to curb elephants. Suffice it to say, the ancient Indian smiths had a thorough knowledge of the importance of carbon alloying and also probably hardening and tempering. These technical skills must have been acquired over a long period

before the craftsmen could have ventured to take up such challenging jobs. The expertise demonstrated in constructing such colossal structure has surprised even modern metallurgists.

The study of the fractured surface of the Konarak beams (Fig. 2A) clearly indicates that it was manufactured by forge-welding square rods of small sections. Jena (referred to by B. Prakash, 1997) and his associates have investigated the nature of these joints, and they have found traces of lead between the two rods, where the forging joint was not perfect. They feel that a large lead bath seems to have been used for uniform heating of a bundle of wrought iron bars to the forging temperature and then forging them together. Since the iron surface is non-wettable by lead, normally it will flow out when the wrought iron bundle is taken out but some molten lead might get trapped in the crevices. Incidentally, some lead has been noticed in Delhi Iron pillar in a recent study, (see R. Balasubramaniam for detail).

From Imperial Guptas to Mighty Moghuls

The technology of iron developed from simple wrought iron to steel, from tiny bits and small objects to colossal structures like victory pillars. The early medieval period following the decline of the Gupta Empire witnessed all over decline and social- political turmoil. But somehow it created greater demand for efficient arms, armour and weapons. Al-beruni's oft quoted observation that in India the farmers continued to till their fields while an army marched by, is applicable to the present situation. It may be worthwhile taking a close, look at the status of iron technology after the Imperial Guptas, during the post - Gupta to Medieval Age.

It is clearly borne out by the Arab and Persian accounts that Indian science received a serious jolt at the hands of the early Muslim invaders. Sheikh Bu Ali Sina who was an eminent scholar refused to accompany Mahmud on his so-called *jehad* to India because he also destroyed, among other things Indian Science (Sarton, 1931). Even Al-beruni has written about how 'Mahmud utterly ruined the prosperity of the country' and how 'Hindu sciences have retired far away' (Sachau, reprint 1983).

Trade and Commerce During the Early Medieval-to-Medieval Period

Though the archaeology of early medieval times is not very well documented, the rich literary evidence of the period does provide valuable data on the socio-economic life. We have already discussed the masterpieces like the Delhi iron pillars that belong to this age (4th –6th century AD).

During the early centuries of the Christian era trade with the Roman world was well established. *Periplus of Erythrian Sea* (Schoff, 1912) testifies to export of Indian iron to Abyssinia in the 1st half of the early centuries of the Christian era. Periplus gives a detailed account of the voyages undertaken by its author and the ports he had visited. The most important harbour was Barygaza, a corrupted Greek form of Bhrigukachchha (modern

Broach or Bharoch) at the mouth of the river Narmada. It was a busy port town where goods were brought in from distant parts of the subcontinent, like Kashmir and Hindukush mountains, so that they could be export to foreign countries. Other port-towns mentioned in the text are Pratishthāna (Paithan), Tagars (Ter), Sopārā and Kalyāna (on Bombay coast). Several places on Malabar Coast also find mention there. The ports of Muchiripattanam and Nilakanth mentioned there also yield old inscriptions saying that these places abound in "ships sent there with cargoes from Arabia and by the Greeks". Indian ships almost regularly sailed to Arabian and African harbours. There is mention of a colony of Indian traders in the island of Socorta.

The articles of export from India from these ports were spices, perfumes, medicinal herbs, pigments, pearls, precious stones, iron, steel, copper, sandalwood, animal-skin, cotton cloth, silk yarn, muslin, indigo, ivory etc. Literary texts, both Brahmanical and Buddhist (especially the Jatakas), refer to rich merchants. Both overland and sea trade prospered from 3rd –2nd century BCE onwards. The luxury goods imported from India flooded the Roman cities. Pliny lamented that India drained the Roman Empire of its gold valued at fifty million *sesterces* and established a favourable trade balance in the foreign markets. There is no reason to doubt that the process must have intensified in the subsequent centuries. The technique of steel making was mastered as is evident from the textual data of Varahmihir (550 AD) who gives an elaborate description of carburisation of sword blades that were in great demand in the world.

During this period, there grew friendly and commercial interactions with the Arabs. In the Early Medieval times, Indian science and technology were at their peak. The early Arab writers of 9th –10th centuries have written profusely about the agricultural practices, fertility of the soil, and techniques adopted by Indian cultivators. They also refer to the metal and metal–working as a successful vocation of specialist craftsmen of this period. *Abhidhānaratnamālā*, a text of this period, makes a list of metals that includes copper, bell metal, iron and steel, lead, tin, silver and gold. Different parts of the country were famous for different metals. *Agni Purana* (CCXLV. 21) describes five centres that were famous for sword making. They are *Khatīkhattara* and *Rishika* (not identified so far), Surpāraka (Sopara) Vanga (Bengal) and Anga (Bhagalpur, Mungher districts of Bihar). Ibn Haukal, (HIED^2 –1.37) mentions the city of Debal in Sind as a famous sword-making centre. Good quality swords were being produced also from iron or steel from Kurij in Kutch.

A 14th century AD work, *Sarangadhara Paddhati* (mentioned by Joshi 1970, p. 82) by the alchemist Sarangadhara describes the technique of manufacturing swords. He mentions several important centres of sword making of his time. Special mention may be made of Kahatikhattara, Rishi, Banga, Shurparaka, Videh, Anga (already mentioned in the Agni Purana, above), Madhyamgram, Bedidesha, Sahagram, Kalinjar. He has also given a detailed account of the quality of iron that was to be used for the manufacture of different types of swords.

In the following centuries, the saliency of Indian iron is well testified by *Ras Ratna Samuchchaya* (RRS), a 10th -12th century text on alchemy. It is not difficult to presume that a well-developed scientific basis must have evolved and they were documented in detail. A very fine classification of different types of iron has been attempted in the text showing a deep understanding of behaviour of iron in the smelting-refining process. Three basic types of iron with different sub-types (according to their properties and nature) have been categorised in RRS.

Some medieval records including that of Barni mention the use of firearms and cannons 13th century onwards. According to Joshi (1970), P.K. Gode in an article 'Use of guns and gunpowder' affirmed use of guns and gunpowder from 1400 AD onwards. A Chinese traveler called Mahum who visited Bengal in 1406 AD mention about the use of guns there. There are also references of its use in Kashmir by 1466 AD and in Gujarat in 1482 AD. The Sanskrit text on polity *Shukraniti* dated roughly around 1600AD mentions two types of firearms used in his times, viz., *Kshudra nalika* (small guns or match locks) and *Brihad nalika* (large guns or cannon). Their measurements have also been specified to be 409mm long having a longitudinal bore of thickness of the middle finger and provided with two raised points for taking aim. The *Brihad nalika* were moved on carriages and their range depended on the thickness of the metal plates. However, the Moghuls were the major users of cannons and continued to manufacture them for centuries.

Ain-e-Akbari gives a detailed account of gun making and the types of guns being made, including the problems and defects and the precision issues. The royal arms and armours were decorated and embossed with gold and silver and occasionally calligraphed, giving details of the weight of raw and finished iron, and the place of origin of iron. The name of the artisan and the place and date of manufacture etc. were carved on the guns. A considerable amount of attention was paid to weapon manufacturing. Ain-e-Akbari (1, 120-21) describes methods of gun making that had been devised by the ingenuity of the emperor himself. 'Ain-e-Akbari'. Even their drawings are given. Indeed this must have been a flourishing industry during Akbar's times.

Production, Distribution and Marketing Mechanism of Iron and Steel

We come across clear references of export of iron and steel. The export was 10,109 pounds of steel in 1657 and over 5 lakh pounds of ironware in 1667 (Raychowdhary, 1982, 275-276). The Dutch imported nearly 20,000 ingots of wootz steel in the 17th century from south India.

The Dutch and the English competed for purchase of commodities like cotton, indigo and even silk. Besides the agricultural produces, salt petre and iron were also in demand. The Dutch purchased large amounts of iron and steel from Golconda region exporting shiploads from Masulipatnam. Moreland (1923, 192) says that the iron-producers in the Golkonda country profited to some extent by the demand from Batavia, since the Dutch export of iron and steel from Masulipatam were at times large. He has further stated, "About the year 1660 the Dutch were active in developing the iron industry in the Godavari delta, and artisans

imported by them appear to have introduced real improvement in technique, but the story to these belong to a later period.”

However, in the northern India, the early invasions of during the 10th –12th AD not only focused on plundering of riches but even on capturing men, women and also children as slaves. "There is little doubt that, like the Julius Caesars invasion of Britain, the Ghaznavid and Ghorian invasions of northern India were partly the undertakings of slave raiders. A successful campaign would be judged not only by the quantities of gold and silver acquired, but also the number of captives, men, women and children, along with horse and cattle." (Habib, 1984, 76-92). The raids were followed by capture of people who were paraded as slaves and many a times sold and transported back to the Islamic countries. Qutbuddin Aibak captured 20,000 slaves from Gujarat in 1195 and '50,000 slaves were brought under chains from Kalinjar. Firuz Tughluq (135-88) enslaved 12,000 artisans'. This practice continued with an intensified pace throughout the medieval period and must have acted as a deterrent and a disincentive for Indian technology, craft and even agriculture; people started deserting villages if such situations arose. Life of people became miserable. Under such a socio-economic condition, science and technology of India was badly hit. The affluence and expertise gave way to misery and fear of oppression. In Alberuni's words who was a renowned scholar of 11th century AD. "Mahmud utterly ruined the prosperity of the country, and performed their wonderful exploits, by which the Hindus became like atoms of dust, scattered in all directions. The Hindu science have fled to places where our hands cannot yet reach...." (Sachau, reprint 1983).

Many Europeans have described poverty and oppression of the peasantry during the Moghul rule. Francisco Pelsart, who spent seven years at Agra as a chief of Dutch factory, was moved by the pathetic condition of the workers and artisans there. He talks of administration of Moghuls and comments "the manner of life of the rich in their great superfluity and absolute power, of the common people in their utter subjugation and poverty - poverty so extreme and so miserable that the life of the people cannot be adequately depicted or described, for here is the home of stark want, and the dwelling - place of bitter woe. Yet the people endure patiently, seeing that there is no prospect of any thing better...... For the workmen there are two scourges, low wages and oppressions.

Observations of Bernier and Tavernier, which are first hand, are a saga of misery and suffering. Bernier spent the years from 1656 to 1658 in the Moghul Empire. He gives a melancholy description of peasantry in his letter to Cobernt. "Even a considerable proportion of the good land remains untilled from want of labourers, many of whom perish in consequence of the bad treatment they experience from the governors.... Some times they fly to the territories of a Raja, because they find less oppression and are allowed a greater degree of comfort". He talks of whole provinces, which became like deserts "from whence the peasants have fled on account of the oppression of the governors". Discussing about the artisans in the cities, Bernier wrote, "It should not be inferred that the workman is held in esteem or arrives at a state of independence. Nothing but sheer necessity or blows of a cudgel keeps him employed---"

This kind of political atmosphere must have been detrimental to growth of a healthy techno-economic atmosphere. The state could hardly provide the right kind of environment conducive to technological innovations leading to an overall prosperity. What is noteworthy, however is that even under such conditions the metal workers could produce admirably excellent quality ware, both for domestic consumption as well as for export. The indigenous iron industry not only survived but also flourished in almost every important iron-bearing region of India. This is clearly borne out by innumerable records of the British period left behind by the explorers, travelers, geologists and engineers of the East India Company and other officials who visited different parts of India.

Status of Indigenous Iron During the British Period

We have noted earlier that the fine steel produced in India had caught the attention of the Europeans as is evident from the description in the records of the Geological Survey of India. There were innumerable and sincere efforts by the British to study the indigenous processes of iron production. Efforts were made to reproduce iron on a mass scale by several British engineers within the country or even back home in Britain.

The iron produced in small sized Indian furnaces was of a very high quality in the opinion of the British expert metallurgists living in the country. In the 19th Century Capt. Presgrave of Sagar (MP) mint analyzed the iron produced at Tendukhera (near Hoshangabad). His assessment is worth quoting here

> *bar iron.. of most excellent quality, possessing all the desirable properties of malleability , ductility at different temperatures and of tenacity for all of which I think it cannot be surpassed by the best Swedish iron; ... the Ageria piece when brought to the bend it showed itself possessed of the power of elongating and stood the bend better than the general run of English iron purchased in the Bazar.*

This iron was very much in demand in the European markets. We have discussed earlier about the Dutch and the Portuguese who were regularly importing Indian iron and steel for centuries before the British stepped on the scene. The latter found it far superior to their own British made iron. For the manufacture of the Britania Tubular and Menai Straits Bridges iron was imported from India in 19th century "...its (iron's) superiority is so marked, that at the time when the Britannia tabular bridge across the Menai Straits was under construction preference was given to use of iron produced in India" wrote La Touche (1918).

There are other observations made by the British experts about the superior quality of Indian steel in the notebook of the British Indian section of the reputed Paris exhibition organized in 1878. On that occasion, Sir George Birdwood commented:

> *"Indian steel was celebrated from the earliest antiquity and the blades of Damascus which maintain their pre-eminence even after the blades of Toledo became celebrated, were in fact made of Indian iron..... The Ondanique of Marco Polo's travels refers originally, as Col. Yule has shown, to Indian steel, the word being corruption of the Persian Hindwany i.e. Indian steel. The same word found its way into Spanish in the shapes of Alhinde and Alfinde first with the meaning of steel and then of a steel mirror, and finally of the metal foil of a glass mirror. The ondanique of Kirman, which Marco Polo mentions, was so called from its comparative excellence, and the swords of Kirman were eagerly sought after in the 15th and 16th countries AD by the Turks who gave great prices for them. Arrian mentions Indian steel 'Sideros indicos' imported into Abyssinian ports" (quoted by Krishnan 1954, p. 70).*

Interestingly, we learn of the quality of Indian steel from accounts of the 1857 Rebellion. In response to what was labeled as an Indian 'mutiny', the British Government confiscated all the swords, daggers and knives from the local people. The Moplas of Malabar had thousands of these weapons which were collected and stored in the warehouse of Calicut. It was resolved by the British that these weapons be destroyed and shredded into 1½ - 2 inches (38.1mm –50.8mm) wide strips and put into blast furnace. Charles Wood commented:

> *The blades of these knives were about 4 inches (101.6mm) wide and 1/16 inch (1.5875mm) in the thick part, and 16 inches (406.4mm) to 18 inches (457.2mm) long, and the handles were of about 8 inches (203.2mm) long. These knives were all made of the native iron from the Indian blast furnaces, and wonderful material they were. To break them was impossible, so a pair of strong hand-shears was made to cut them up. But the remarkable point was this, that if put into the shears with the thin cutting edge first, they could not be cut at all, but notched the shear blades immediately. (Wood, 1894, p. 179).*

Thus as late as the 19th century, steel this high of a quality was being manufactured. Understandably, the British forces grew hostile against both the industry as well as the product. Naturally, measures would have been taken to curb iron production.

Summary and Discussion: The Colonial Ambition and Stagnation of Iron Production

The European intervention by way of establishing their own plants adversely affected the existing domestic iron production system. Ironically, it did not even prove profitable for them. The number of iron producing units started declining (as well testified by the precise data from M.P., given above). In 1852, Oldham studied the Birbhum indigenous iron industry. He reported about the presence of 70 furnaces, which produced about 2,380 tons unrefined iron annually. But the number of furnaces and along with that the production started sliding down under the changed condition. The situation further declined with import of much cheaper pig iron.

In Kumaon there were 121 furnaces till 1855 which produced iron in villages like Bhabur, Dhuniakote, Agar, Ramganga etc. The richness of resources and availability of cheap labour towards a profitable iron working had led Europeans to indulge into setting up iron industries of their own in Kumaon. The expansion of railways raised the need of iron, which provided further incentives for such ventures.

The colonial system in Kumaon worked for nearly 130 years, first under the British East India Company and later under the British Crown. A micro level study of the Swedish venture in Kumaon by Jan of Geijerstam (2002) is revealing. In 1860, Julius Ramsay, a Swedish engineer took charge of the Kumaon iron works which was originally started by the British. But the project was abandoned within two years. It was restarted in 1870, but finally abandoned in 1879. Concluding his examination Geijerstam comments,

> *The Kumaon Iron Works, as well as the Burwai Iron Works and the efforts to build an iron industry in the Madras Presidency, expose the long held ambition to build a modern iron and steel industry in India. But these efforts were, although recurring, isolated, …The governments could have, but did not play the decisive role, either in creating the infrastructure for its development or the economic conditions to carry it through…*

Eventually problems kept on cropping up at these industries and gradually the 'plants' started shutting down one by one, (see Geijerstam 2002). A lack of understanding of the local temper, marketing and socio-economic factors, mismanagement etc. combined with near absence of governmental support appears to be the root cause of failure of such adventures. Importantly, they also unsettled the well-entrenched system of indigenous iron production.

However, another critical reason for the decline of Indian Ironworks underlined by Geijerstam (op cit, 184) is the "…Imperial interest in limiting competition and securing markets for the British Industry. The cotton spinners of Lancashire and the iron and steel producers of Sheffield had fundamental common interests in this respect". Thus the colonial attitude of the British combined with the inherent internal weaknesses of the indigenous iron industry brought an end to this great tradition. Ball's comment about the declining phase of indigenous iron working is revealing,

> *.... the manufacture of iron has in many parts of India been wholly crushed out of existence by competition with British iron, while in others it is steadily decreasing and it seems destined ultimately to become extinct. For this reason alone, if there were no others, the native process is worthy of full notice, but there are other strong reasons why it should be described, and which demand for it our respectful consideration and administration.... (Ball 1881).*

These observations proved almost prophetic and the indigenous iron industry did indeed whither away. However, recent interest in the indigenous industry has brought forth evidence

of stray survival of traditional iron working in certain remote parts of the country. The British and the Swedish ventures fell under their own weight. It could also be due to lack of political will or under some colonial strategy that these works had to be shut down. The innovations, the expertise and the researches that were applied all proved futile and of little avail.

Survival of Indigenous Iron Industry

It appears that the smallness of the industry was an asset because the activity could shift without any difficulty to a more suitable area. James Franklin (1829) underlined this appropriateness that the 'workshop', even the furnaces need not be 'transported from place to place, the implements being the only things to carry; it may be erected in places which combine the advantage of proximity of ore and fuel ...and may be erected for temporary purposes and abandoned when the objects is fulfilled without material loss...". Therefore he thought the "cheapness of labour and fuel that I question whether any other furnace could compete with it and if by improvement it can be made capable of working on a larger scale, arsenal materials, materials of bridges and other heavy work –it certainly is an object worthy of attention as a great saving of expense might be affected by its use". Our own study substantiates this. The traces of iron smelting expand over a very large area in the ore-rich forests in the Sonbhadra- Sidhi region, (Fig. 3, 4). The smelters still reside in these remote areas amidst the older remains of iron working that has discontinued now. But the appropriateness of their 'craft' was their main strength. The indigenous worker somehow managed to survive. This unorganized sector could therefore, be given the credit of being the savior of the tradition of iron technology from the ancient times. The foregoing discussions clearly bear it out that the cottage industry that was persevered in the remote tribal zones had the tenacity to survive and preserve the age-old metallurgical tradition against great odds. Subsequently these ethnic societies were generally marginalized and oppressed. Though, they wilted, they did not wither away. They may be given the credit for carrying the legacy of a glorious tradition of iron and steel manufacturing for which India was once famous all over the world. We may briefly talk about some of these groups we have had the privilege to study.

The Asurs of Netarhat plateau are said to be the oldest iron smelting community of India. Unfortunately, the laws to protect the forests have now curbed the practice of charcoal making which has badly hit the traditional iron making industry. Even as early as 1940 when Ruben went to see the Asur smelting in Netarhat, he could barely find workshops which were still active in the true sense. (Recently, some have been revived by Bishun Bharti, Fig. 5).

In 1959 Elvin visited Netarhat and he also observed that ‘The smelting and smithy industry had almost entirely disappeared’. Elvin prepared a report on the status of the tribe and their working stating:

> *…surely where iron is in the blood of a small tribe, efforts should be made to encourage it. The Asurs seem to have given it up when their forests came under official control and they could no longer obtain sufficient wood for charcoal. If this*

> *could be straightened out, they might take to their ancient craft, at least as a subsidiary industry, for here is something that is already there. (Elvin, 1963.)*

Leuva who wrote a monograph on the Asurs is in agreement with Elvin suggesting that there should be a training-cum-production center for the Asurs,'A few forest coupes should be earmarked for the Asurs so that they can make charcoal required for iron-smelting; and that they should be encouraged to take up their ancient craft again.'

Elvin wrote, "It (iron smelting) was brought to an end as a result of politics adopted by a foreign Government and these people, already poor, have thus been deprived of that little extra which would make just the difference between hunger and sufficiency" (in Leuva, 1963, 70).

Not far from the Asur belt of Netarhat plateau we come across the Agaria belt. Interestingly, there is evidence of extensive iron working in Sonbhadra-Chandauli districts where there is a hill called Lohsanwan, and Geruwatva Pahar or a 'hill of iron' (ore). This place, in the heart of India, could be one of the original iron-producing centers in the land. The earliest radiocarbon dates from iron bearing levels, as has been pointed out earlier, came from the recent excavations in the Vindhyan plateau which takes the antiquity of iron working in this region to a hoary past, (*c.* 1500-1400 BCE if not earlier). Thus one may trace iron-working evidence in this region from the 2nd millennium BCE to the modern times–an exclusive evidence of its kind anywhere in the world.

Ch 7

Marvels of Indian Iron through Ages

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Introduction

The glorious tradition of iron making in India has been well researched in the recent past and Professor Vibha Tripathi has detailed a comprehensive history of iron technology in the Indian sub-continent as one of the Infinity-sponsored books. The present book will serve as a companion to the comprehensive history by highlighting the marvels of Indian iron through the ages, with specific emphasis on large iron objects that still exist in different part of the subcontinent.

The Delhi iron pillar is a well-known example and is briefly mentioned. Special attention has been drawn on other large iron pillars like the ones that exist at Dhar, Konarak, Mandu and Kodachadri hills. The engineering features of these objects have been described in detail as well as their history.

Another class of large iron objects that demand critical attention is large forge-welded cannons. There are several unique features to notice in the large number of forge-welded cannons found in the Indian sub-continent. In fact, the number of such cannons far outnumbers any similar cannons in the rest of the world. All the emphasis has been on forge welded cannons because, unlike the cast iron cannons, which were introduced in India by the European colonial powers, the forge welded cannons are true examples of the medieval Indian blacksmith's skills. Some salient features of forge welding cannon technology and associated catalogue of important forge-welded iron cannons of India have been provided. Special attention is focused on their design and possible method of construction. The final example of the marvel of Indian iron metallurgy that will be described in the book is wootz steel. Salient features of wootz steel have been described and the thermomechanical processing of the wootz cakes into tough swords have been highlighted from a metallurgical viewpoint bringing out the skill and workmanship of Indian blacksmiths.

Research Already Done on Indian Iron Technology

The primacy of iron technology in the Indian sub-continent is well established and there are several published books on the state of ancient Indian iron technology. These scholarly publications have addressed the primacy of iron in the Indian sub-continent, its local origin as opposed to western diffusion, and the archaeological and literary perspectives that are available. These learned publications deal with several aspects of iron technology with respect to the Indian sub-continent. Though these scholarly books provide a strong foundation for studies on iron in the Indian sub-continent, the wonderful examples of Indian iron technology have not been dealt with in detail in these publications, except for detailed studies of the Delhi Iron Pillar (Balasubramaniam 2002) and wootz steel (Srinivasan and Ranganathan 2004). Most of the scholarly books on ancient Indian iron do, however, refer to such examples in the main text without delving deep into these examples.

The Inspiration and Purpose Behind Exploring India's Iron Marvels

This Infinity book project was commissioned in April 2003 and its focus was originally on the metallurgy of ancient Indian iron. A vast amount of literature on the subject was collected and surveyed. The sketches for the book were made and the initial draft was prepared by summer 2004. At that point, it was realized that the book was turning out to be more of a technical monograph, which may serve as a good technical reference for serious scholars and researchers on the subject, but certainly not one that would catch the imagination of the reader. My original book on metallurgy of ancient Indian iron was written keeping the learned audience in mind, and frankly, it was turning out to be too cumbersome for the common reader. As one of the visions of Infinity Foundation is to bring out the glory of history of Indian science and technology, it was imperative to prepare a book that will be enjoyed by the common reader and at the same time, possess strong technical contents.

One of the main aims of our research into India's rich metallurgical past is to excite and inspire young minds by presenting the wonderful achievements of metallurgical knowledge and practice in ancient and medieval India. Another aim has been to inform the eager and interested non-Indian reader about the wonders of Indian metallurgical skill. In this regard, the Infinity Foundation has pioneered the study and diffusion of Indian traditional knowledge systems by documenting the history of science and technology of India. It was finally decided that a book dealing with wonderful examples of Indian blacksmithy skills would interest the general reader more than a learned tome on the technicalities of Indian iron through the ages.

Contents of the Volume

Once it was decided to focus attention on the marvels of Indian metallurgical knowledge and skill, with particular reference to iron metallurgy, the task of putting together this book became much easier. Earlier, an enormous amount of literature had to be reviewed and sorted carefully in order to summarize them for the subject of metallurgy of ancient Indian iron. However, for the book dealing with the wonders of Indian blacksmithy skills, there was a ready source of reference, namely our original works dealing with several different objects that display India's metallurgical genius. Therefore, this book draws inspiration and major material from our original publications on this subject, especially on large iron objects. However, there is one area that has been personally researched by the author and this is the wonder material of the Orient, namely wootz steel. Material for this subject has been collected from existing literature.

The book is divided into four major sections. In the first introductory chapter, some basic ideas of iron metallurgy with specific reference to the Indian sub-continent are presented. This does not call for detailed knowledge of science and metallurgy. A basic high school background in science would be sufficient to understand most of the material presented in this chapter. The aim of writing this chapter was not to review the entire gamut of metallurgy of ancient Indian iron, but to provide the reader a glimpse into the wonderful knowledge which was used to manufacture the wonderful objects presented in the book.

Massive Iron Objects (Pillars and Beams)

The second chapter deals with massive iron objects, with special reference to pillars and beams. The most famous example, of course, is the Delhi Iron Pillar (Figure 1) and most of the material presented on this metallurgical wonder is based on the author's own research. The other well-known iron pillar located at Dhar has also been described in great detail. The story of the Dhar Iron Pillar (Figure 2) also makes for a fascinating reading. The iron beams from the Orissa temples have been described (Figure 3), with material drawn essentially from literatary sources. A description of the Iron Pillar at Kodachadri hills finally completes the chapter.

Indian Cannon Technology

One of the less-known wonders of the Indian blacksmith is the forge-welded cannon. A large number of such cannons are located throughout the length and breadth of the Indian sub-continent in famous historical locations. The forge-welded cannons are specifically addressed and not cast iron cannons because cast iron technology did not originate in India. Incidentally, this appears to be one of the adverse impacts of the Indian iron metallurgical tradition. Indians were so adept at reducing iron oxide in the solid state (using bloomery furnaces) and then forge welding them to practical objects that they did not find the need to invent, develop and adopt cast iron technology from China and Europe. It is clear that one of the important reasons is the proficiency of the Indian blacksmiths in the science and engineering of handling wrought iron that they never felt the need to adopt to cast iron technology. The India forge-welded canons will be shown to be proof of this. We find a

large number of massive forge welded cannons in the Indian subcontinent, much greater than that found in the rest of the world. Some of these pieces are truly gigantic like the *Landa Kesab* at Bijapur manufactured in 1646 and weighing almost 47 tons (Figure 4). Therefore, the forge welded cannons of India must first be viewed from a historical perspective. Some wonderful examples of forge-welded cannons of the Indian sub-continent have been outlined, providing their history, construction and manufacturing technology. Some interesting examples of forge welded cannons at Thanjavur (Figure 5), Bishnupur (Figure 6), Hyderabad (Figure 7) and Jhansi (Figure 8) are depicted.

Some unique Indian inventions in cannon technology, like the manufacture of composite cannons (i.e. iron interior and cast bronze exterior) will be highlighted with examples (a composite iron+bronze cannons called *Azdaha Paikar* from Golconda fort in Hyderabad is shown in Figure 9).

Interesting stories of India's command of the world salt petre market by the 18th century (salt petre was used in the manufacture of gunpowder) and the European mercenary artillerymen serving in Indian states during the period 1500-1800 AD have also been included.

Wootz Steel

The final chapter briefly reviews the wootz steel of the Indian sub-continent. This was a highly prized commodity during the medieval period (1000 – 1750 AD) for its wonderful ability to be thermomechanically processed into tough swords, which exhibited typical *damascene* patterns (i.e. water-line patterns) on their surface. The wootz steel was highly regarded all over the world and thus can truly be referred to as an engineering material with a large geographical spread. Most important is that wootz steel originated from the Indian sub-continent. The chapter will highlight the wonderful properties of wootz steel, the methods of their production, the making of tough blades from wootz pancakes and finally the European fascination with this wonderful material. Modern day duplication experiments have been also briefly reviewed at the end.

Historical Perspective

The concluding chapter will place all the objects that have been discussed in a historical perspective to highlight the achievements of ancient Indians mastery over iron and steel technology. The care required to conserve and preserve these wonderful objects have also been discussed. The chapter will finally highlight possible modern-day applications for the technologies that went into the making of these wonderful iron objects of the Indian sub-continent.

Bibliography and References

The book ends with a detailed bibliography of the subjects discussed in the text. The bibliography has been presented in a detailed manner in order to assist eager readers to find

other original publications where the topics in the present volume are discussed in greater depth and detail.

It is sincerely hoped that the book will inspire readers and ignite a spark of curiosity and interest, enough so that they may even wish to learn more about Indian skills in iron metallurgy.

Ch 8
ZAWAR: THE OLDEST COMMERCIAL ZINC PRODUCTION CENTER

J.S. Kharakwal

Contents:
1. EARLY EVIDENCE OF ZINC AND BRASS IN INDIA
2. LITERARY EVIDENCE
3. GLOBAL PERSPECTIVE
4. ZINC PRODUCTION AT ZAWAR
5. CONCLUSION

Zinc (Zn) is a bluish- white, yellow, brown or black coloured base metal. Its chief and important minerals are sphalerite or zinc blende, smithsonite, calamine, zincite, willemite and franklinite. As it boils over at about 900^0 C, it is difficult to smelt and hence zinc technology was mastered later than that of copper and iron. For pure zinc production, it was required that a distillation technology be developed. India has the distinction of being first civilization in the world to ever do so.

Below we will trace the evolution of zinc technology in a global perpective.

1. EARLY EVIDENCE OF ZINC AND BRASS IN INDIA

Only a few Harappan bronzes have been found with zinc content, and even then the percentage of zinc in the alloy is small. For example Lothal, a Harappan site in Gujarat (2200-1500 BCE) (Rao 1985), has yielded around half a dozen copper based objects containing zinc, with zinc content ranging from 0.15 to 6.04 % (Nautiyal *et al.* 1981). One of the objects (antiquity no. 4189), though not identified, contains 70.7% of copper, 6.04 % of zinc and 0.9% Fe, which could be termed as the earliest evidence of brass in India. In Kalibangan, a long spear head of copper was found containing 3.4% of zinc (Lal *et al*. 2003: 266). Unless we have more examples of bronzes containing appreciable percentage of zinc replacing tin, arsenic or other elements, we can not infer that the Bronze or Early Iron Age cultures were aware of the nature and property of zinc. Nevertheless, these examples represent the early or experimental stage of zinc in India.

The archaeological record indicates that in the second half of the first millennium BCE the percentage of zinc started increasing and intentional brasses appears. Such evidence has been found from Taxila, Timargarh and Senuwar. Taxila, located about 30 km north of Rawalpindi in Pakistan, has yielded a large variety of metal objects including those of copper, bronze, brass and iron (Marshall 1951:567-69). Several brass objects datable from the 4th century BCE to 1st century CE have been discovered. One of them was a vase from Bhir mound, which predates the arrival of the Greeks at Taxila (Biswas 1993) and has assayed 34.34 % of zinc, 4.25% of tin and small quantity of lead (3.0%), iron (1.77%) and nickel (0.4%). Another evidence of real brass was discovered recently at Senuwar in the

Ganga Valley from the Northern Black Polished Ware (NBP) levels (Singh 2004: 594). It has 64.324% of copper and 35.52% of zinc.

Before we continue, it will be useful to discuss some metallurgical details regarding zinc and brasses. Brasses made by a cementation method generally contain less than 28% of zinc and rarely could go up to 33% (Werner 1970) but in the Taxila and Senuwar examples, the percentage of zinc is more than 33%. Therefore, these are the earliest definite examples of real brasses which must have been made by mixing metallic zinc with copper. Zinc is a volatile metal and thus has low boiling point (907°C). Since the temperature zinc could be smelted at is higher than zinc's boiling point, extracting pure zinc from ore by smelting becomes difficult. Unlike other metals, it comes out in the vapour form from the furnace and gets reoxidised if it is not condensed.

Zinc ore was mined way back from 5th century BCE ((PRL 932 430±100 BCE; BM 2381 380± 50 BCE) at Zawar and metallic pure zinc was produced here by distillation process for the first time in the world. The production of metallic zinc has been traced back to 9th century CE at Zawar, but there is a strong possibility that the older evidence is buried under the immense heaps. Though the Taxila folks were aware of the distillation process (Habib 2000), in the absence of definitive evidence I can not claim that they employed this process for obtaining zinc. It is possible, though not proven, that metallic zinc was produced at Zawar way back from the 6th century BCE, from where it was obtained both at Taxila and Senuwar. The other possibility is that metallic zinc was scrapped from the cooler parts of the furnaces at both sites.

Besides these, Prakash (Athavale and Thapar 1967: 132 table IV) and Mahurjhari in Mahararashtra (Deo 1973; Joshi 1973:77), Asura sites in Chhotanagpur region (Caldwell 1920: 409-411; Roy 1920: 404- 405) have yielded brasses, which have been dated to the second half of the first millennium BCE. Most of these brasses have more than 15% of zinc and some of them contain between 22 to 28 percent of zinc. This kind of evidence clearly points out they were made by cementation process.

Another interesting use of brass in early India was in the minting of coins. Several circular or rectangular punch marked and other coins of brass are known mostly from northern India, which are bracketed between the 2nd century BCE and 4th century CE (Smith 1906) (see table 2). Interestingly most of these coins belong to the regional kings, indicating popularity of brass in India.

Table 2: Early brass coins of India (After Smith 1906)

No.	Period	King/Site	No.	Shape	Reference
1.	200 BCE	Gomitra	1	Not stated	Smith 1906: 205
2.	200 BCE	Mitasa (Gomitra?) or	1	Not stated	Smith 1906: 205

		Satasa			
3.	2nd cent. BCE	Unidentified	1	Not stated	Smith 1906: 194
4.	2nd cent. BCE	Gomitra (Mathura)	1	Circular	Smith 1906: 193
5.	2nd cent. BCE	Uttam CEatta (Mathura)	1	Not stated	Smith 1906:193
6.	2nd cent. BCE	Bhavadatta (Mathura)	1	Not stated	Smith 1906: 193
7.	2nd cent. BCE	Purushadatta (Mathura)	1	Not stated	Smith 1906: 192
8.	2nd cent. BCE	Amoghbhuti (Kuninda king)	6	Circular	Smith 1906: 168-169
9.	2nd cent. BCE	Rajanya (Naga or Narwar)	4	Not stated	Smith 1906: 179-180
10.	2nd cent. BCE	Asvaghosa (Kosam)	1	Circular	Smith 1906: 155
11.	150 BCE- 100 CE	Dhana Deva (Ayodhya)	1	Rectangular	Smith 1906: 148
12.	150 BCE- 100 CE	Siva Datta (Ayodhya)	3	Rectangular	Smith 1906: 149
13.	150 BCE- 100 CE	Ajaverma (Ayodhya)	1	Circular	Smith 1906: 150
14.	125- 80 BCE	Hagamasha (Satrap of Mathura)	1	Not stated	Smith 1906: 196
15.	100 BCE	Audumbara king	1	Circular	Smith 1906: 166
16.	1st cent. BCE-CE	Yaudheya kings	3	Not stated	Smith 1906: 181
17.	1st cent. BCE-CE	Agnimitra (Panchala and Kaushala)	2	Circular	Smith 1906: 186-187
18.	1st cent. BCE-CE	Bhumitra (Panchala and Kaushala)	1	Circular	Smith 1906: 187
19.	1st-2nd cent. CE?	Devasa (Kosam)	8	Circular	Smith 1906: 207
20.	1st -2nd cent. CE	Unidentified	1	Rectangular	Smith 1906: 201
21.	2nd cent. CE	Unidentified	2	Circular	Smith 1906: 203-204
22.	3rd -4th cent. CE	Pasaka (Kushana type)	1	Not stated	Smith 1906:89
23.	Medieval	Unknown (Jajjapurai) Sri Siva type	1	Not stated	Smith 1906: 333
24.	3rd -4th cent. CE	Basata (later Kushana)	5	Not stated	Chatterjee 1957:103

Beside coins, several brasses have also been reported from the Early Historic sites in Uttar Pradesh, Madhya Pradesh and Gujarat, which include lids, caskets, bangles, finger rings, utensils, icons, chariot and religious object and utensil (Biswas 1993, 1994: 360; Biswas and Biswas 1996:132).

LITERARY EVIDENCE

Ayurvedic treatises such as *Susrut Samhita* (5th century BCE) and *Charak Samhita* (2nd century BCE) recorded the use of the essence of various minerals and metals e.g., gold, silver, copper, tin, bronze and brass for the preparation of medicine. These texts also mention that the instruments used for curing delicate parts of the body were made of gold, silver, copper, iron, brass, tooth, horn, jewels and of special varieties of wood (Datt Ram 1900:12; Sharma 2001 II: 444). Both these texts record brass as *riti* or *ritika*.

Another interesting case of zinc being used for medical purposes is in the use of a substance called *pushpanjan*. It is interesting is that both the *Charak Samhita* and *Susruta Samhita* refer to *pushpanjan,* which was prepared by heating a metal in air and was used for curing eyes and wounds (Chikitsasthanam 26.250) (Shukla and Tripathai 2002: 661; Ray 1956: 60). This substance could be identified as zinc oxide since, as Craddock (1989: 27) points out, "no other metal would react in the air to produce an oxide suitable for medicinal purpose". Therefore these Ayurvedic texts are perhaps the earliest literary evidence of zinc in India.

Kautilya's *Arthasastra* is one of the earliest firmly datable (4th century BCE) textual evidence for the use of brass. The *Arthasastra* reveals that the director of metals was responsible for establishing factories of various metals such as copper (*tamra*), lead (*sisa*), tin (*trapu*), brass (*arakuta*), bronze (*kamsa* or *kamsya*), *tala* and iron (Kangle 1960 vol I: 59 and vol II: 124; Kangle 1972 vol II: 108). Brass has also been frequently mentioned in other ancient Sanskrit and Buddhist literature and was popularly known as *harita, riti, ritika, arkuta* or *arkutah, pitala* and so on (Chakrabarti and Lahiri 1996: 149; Neogi 1979: 41; Sastri 1997:208). The term *kamsakuta* of *Digha-nikaya* and *Dhammapada Atthakatha* has been interpreted as brass coins by Chatterjee (1957: 104-111). He strongly argues that brass currency was in vogue between 6th and 4th century BCE in India, though we don't have chemical analysis of known coins of this period.

We also find literary evidence from foreign observers during this period. Strabo, quoting Nearchus, who traveled to the north-western part of the Indian subcontinent with the Macedonian army in the 4th century BCE, tells us that Indian brass was cast, and not forged. He also mentions that the vessels made of cast brass broke into pieces like pottery when they fell.

Thus, all the aforesaid archaeological and literary evidence clearly points out that Indians had started using ores rich in zinc from second millennium BCE and begun to produce intentional brasses from the first millennium BCE. The discovery of a large number of coins (see below)

and other objects indicates that it became popular in the second half of the first millennium BCE. Darius I, a Persian king, had a few Indian cups which were indistinguishable in appearance from gold except from their smell (Hett 1993: 257). This may be describing the features of Indian brass.

Brass in Religious Iconography

Since zinc could change the colour of copper and impart it a golden glitter, it was preferred for making a Hindu, Buddhist and Jain icons throughout the historical period. For example the brasses of the Himalayan region (from Tibet to Gandhar) have appreciable lead content while the percentage of zinc varies from 4 to 35 (Chakrabarti and Lahiri 1996:108-109; Reedy 1988). Obviously these brasses were made by the selection of ore, cementation process, and mixing metallic zinc with copper. In the absence of a source of zinc in the Himalayan region, it may be suggested that metallic zinc was supplied from Zawar. The higher percentage of lead in these brasses clearly suggests that it was deliberately added to increase the casteability of the metal. Such leaded brasses were called *kakatundi* in ancient India.

Craddock (1981:20-31) analysed 121 Tibetan and Himalayan icons/metal works by atomic absorption spectrophotometer for 13 elements in each sample down to the 10ppm level. He has shown that as many as 45 artifacts have more than 28% of zinc which might have been made by mixing copper and zinc. The percentage of zinc in such artifacts ranges from 28 to 54. It seems that most of the brasses on his list belong to Medieval and later Medieval times.

From Phopnarkala and East Nimar, in Madhya Pradesh, several standing Buddha images made of brass have been discovered (Sharma and Sharma 2000). They have been assigned to the Gupta-Vakataka period (5th – 6th century CE). These brasses contain high percentage of zinc, ranging from 21 to 30%, which means that they were made by cementation process.

In the first half of the seventh century CE (629-645 CE) Hiuen Tsiang, a Chinese scholar of Buddhism, extensively traveled in India. He saw a magnificent *vihara* (residential complex of Buddhist monks) of brass near Nalanda under construction during the reign of Raja Siladitya (Harshavardhan 606-647 CE). It would have been more than 100 feet long when completed (Beal 2000vol ii: 174). He also noticed brass images (*teou-shih*) of Buddhist and Brahmanic deities at several places in northern India (Beal 2000 vol.i : 51, 89, 166, 177, 197,198, vol.ii: 45, 46, 174).

The metal art of Eastern India, mainly from Bihar, West Bengal and Bangladesh, is also fairly well known. A large number of ancient bronzes, belonging to the Pala and Sena Schools of art are datable from 8th to 12th Century CE and contain considerable amount of zinc (Leoshko and Reedy 1994; Pal 1988; Reedy 1991a, b).

A large number of bronzes and brasses, mostly icons of Jain and Hindu deities, containing appreciable amount of zinc have been reported from various parts of Gujarat, and are datable to 6th to 14th century CE.

Most of these late medieval brasses were made by mixing metallic zinc with copper as the percentage of zinc has been found to exceed more than 28 %. In some cases lead is present at levels up to 9.5%, which must have been useful in rending fluidity to the metal. It is likely that all these brasses were made by using metallic zinc from Zawar. The icon of seated Tirthankara, dated 1752 CE, from Gujarat is one the finest example of late medieval brasses in India and was made just a few years before the Maratha invasion of Mewar (Biswas 1993).

Bidri Ware

The Bidri Ware of if Bidar in South India is well known for its glossy black surface decorated with exquisite silver inlay art (Gairola 1956). Typically, the wares are a zinc alloy decorated with silver or gold inlay. La Niece and Martin (1987) have done detailed technical studies of 27 vessels of this ware from the Victoria and Albert Museum's collection. Their results show that the content of zinc varies from 76 to 98%, copper 2 to 10%, lead 0.4 to 19%. Lead isotope studies have indicated that the metallic zinc of Bidri ware was not obtained from Zawar (Craddock et al. 1989: 52-53).

Although arcaheometallurgical activity at Zawar was casually recorded by several British and Indian scholars in the 19th and the early 20th century, credit for attracting the attention of the international community to the immense remains and extensive mining activity of zinc must go to Carsus (1960), Morgan (1976), Strackzeck *et al.* (1967) and Werner (1976). Perhaps these reports encouraged P.T. Craddock of the British Museum and K.T.M. Hegde of M.S. University of Baroda to initiate an archaeometallurgical study at Zawar jointly with Hindustan Zinc Limited, Udaipur in 1983 (Bhatnagar? , Craddock *et al* 1983, 1985; Gurjar et al …..; Hegde 1989; Paliwal *et al* 1986; Willies 1984). This team carried out extensive investigations both for ancient mining as well as smelting of zinc at Zawar. They found primitive smelting retorts from the dam fill at Zawar and the evidence of furnaces at old Zawar and Zawarmala. The entire valley of the Tiri in Zawar is dotted by massive dumping of slag and smelting clay retorts. This indicates a long tradition and commercial production of zinc. Several radiocarbon dates bracketed between 12th and 18th century also conform this activity. Gurjar et al. .. 633) write:

> *…the earliest evidence of zinc smelting on industrial scale is the carbon date of 840$\pm$110 CE for one of the heaps of white ash removed from zinc smelting furnace. The fragment of relatively small, primitive retorts and perforated plates found in the earth fill of dam across the Tidi (Tiri) river may belong to the period or they must at least predate the dam itself. It appears that the main expansion of the industrial phase of zinc production began at Zawar sometime from 11th or 12th century*

Literary Evidence of Zinc Distilling Processes

The alchemist Nagarjuna is well known for his treatise on alchemy titled *Rasaratnakara,* which was perhaps originally written between 2nd and 4th century CE and compiled around 7th or 8th century CE (Biswas 1993: 317, 1994: 361-362; Ray 1956: 116-118). Nagarjuna was certainly a great scientist, who, for the first time, not only described cementation processes but also zinc production by a distillation technique (Biswas 1993: 317; 1994: 361-362; Ray 1956: 129). This is, therefore, the earliest literary evidence which records brass as an alloy of copper and zinc.

Rasarnavam Rastantram, an alchemical text datable to 12th century CE, is an important alchemical text, in which both brass and zinc have been recorded. This text clearly records a zinc making process (Craddock *et al.* 1989: 31; Ray 1956: 118) and also different kinds of zinc ores e.g, *mratica rasak, gud rasak and pashan rasak*.

Apart from these there are a few other alchemical texts such as *Rasakalpa*, *Rasarnavatantra, Rasprakash Sudhakar* of Yasodhara, *Rasendrachudamani* of Somadeva and Rasachintamani of Madanantadeva (all datable from 10th to 12th century A.D) that describe different kind of brasses and zinc-making by a distillation process (Ray 1956: 171-191). The description given by Yasodhara for the extraction of zinc appears to be the best one as Craddock *et al*'s (1989) work has shown that it matches well with the process used at Zawar. These texts reveal that *koshthi* type furnaces were used for smelting and had an arrangement of two chambers separated by a perforated plate. For distillation, *tiryakpatana yantra* were used.

The *Rasaratnasamuchchaya,* a late 13th or early 14th century work of iatro chemistry, is the best available literary evidence of zinc production process. In fact, the zinc smelting process described by Yasodhara previously had more or less been repeated in this text with the addition of illustrations of apparatus by Somadeva. Bhavamisra in the 16th century in his well known work, *Bhavaprakasanighantu,* recorded as many as seven different kinds of alloys (*upadhatus*) including bronze and brass (Chunekar and Pandey 2002: 609). He has recorded two different kinds of brasses such as *Rajariti* and *Brahmariti*. In addition to these, two other types of brasses (*pittala) i.e., ritika* and *kaktundi* have also been recorded (Neogi 1979: 41).

Also, Allan (1979: 43-45) cites the work of Abu Dulaf, *Al-risalat al-thaniya,* datable to 9th – 10th century CE, who described production of a variety of *tutiya* in Iran. He recorded that the Indian *tutiya* was preferred in Persia (Allan 1979: 43-45), which indicates that it was superior to the Persian variety. It is likely, therefore, that the Persians imported Indian *tutiya*. The Persians also recorded Indian *tutiya* as the vapour of tin (Allan 1979: 44), which might be zinc (Craddock *et al*. 1989: 74) from Zawar. The Persian literary source also supports production of zinc in India in 9th-10th century.

All the aforesaid literary references clearly suggest that metallic zinc was known in India several centuries before the actual dated evidence of commercial production at Zawar.

There is interesting evidence of several distillation furnaces at Zawarmala. These funaces are square-shaped on plan (66x69cm) which could have the shape of truncated pyramids and were about 60 cm in height. An even bigger furnace (base 110 cm square) has been reportedly found at old Zawar which may have been used for bigger retorts. The furnaces had two chambers, the upper and the lower, which were separated by a perforated plate of bricks. The smiths of Zawar innovated **bringal** shaped retorts, ranging from 20 to 35cm in length and 8 to 12cm in diameter, for distillation of zinc. These inverted retorts were placed in the upper chamber for firing and the zinc vapour was condensed through distillation in the lower one. Thus, for the first time anywhere in the world pure zinc was produced by the distillation process on a commercial scale. Craddock (1995:309-321) compares these furnaces with *koshthi* type furnaces illustrated in *Rasaratnasamuchchaya* and other earlier texts on alchemy. An ingenious method was devised for downward distillation of zinc vapour by the Zawar metallurgists. Thanks to the joint efforts of the Hindustan Zinc, the British Museum and M.S. University Baroda, the oldest zinc industry of the world could be brought to light.

GLOBAL PERSPECTIVE

Europe

Claims of early zinc and brass being present in several parts of Europe and the Middle East e.g., Switzerland, Greece, Cyprus and Palestine have been made by Eurocentric scholars. However, all these claims, except for the evidence of the sheet of zinc from the Athenian Agora (300 BCE), are doubtful. Recent studies have shown that small percentages of zinc may occur due to accidentally use of copper ore associated with zinc or its ore.

In Europe, William Champion established a zinc smelting furnace in 1738 CE and started commercial production in 1743. His furnace employed downward distillation technology and was, in fact, quite similar to Zawar furnace designs (Day 1973:75-76). What is interesting is that Champion used exactly the same technique of distillation *per descensum* that was used at Zawar and even used 1.5% (weight) common salt in the zinc –smelting charge (Biswas 1993:327). His arrangement of retorts and technique were identical to those of Zawar.

Dr. Lane is believed to have smelted zinc ore at his copper work in Swansea in 1720 (Porter 1991: 60) around 20 years before Champion started zinc production in England. Is it not impossible that the very Dr. Lane who went to Zawar in India, learnt zinc smelting techniques and even attempted it at Swansea passed on this plundered technology to the likes of Champion, Henkel, and others.

China

In China, brasses containing up to 25 percent zinc have been reported on since the fifth and third millennium BCE, but they did not play any role in the development of zinc production. It is generally held that the Chinese started using zinc and brass from the last quarter of the third century BCE when the Han Dynasty flourished in China. Even so, actual brass (*thou-*

shih) doesn't appear before the 3rd century CE. Craddock and Zhou have suggested that zinc was introduced in China through Buddhism around 2000 years ago. However, Weirong and Xiangxi (1994: 16-17) inform that the earliest literary record about brass mentioned as *tutty* is known from the Buddhist literature belonging to the Tan dynasty (619-917 CE).

Bowman et al. (1989) have analyzed 550 coins ranging from the 3rd century BCE (Zhao dynasty) to the late 19th century (Ch'ing dynasty). They have found that the percentage of zinc suddenly increased more than 20% or even up to 28% in brasses in the early 17th century CE. This phenomenon is also supported by the well known textual evidence of *T'ien Kung K'ai-Wu,* written in 1637. It is the first definite evidence of metallic zinc in China which also mentions details of alloys used for coins.

Craddock gives credit to the Portuguese ships for transporting zinc from India to China and eventually introduction of zinc technology. He emphatically states that the Zawar process is the ancestor of all known zinc smelting techniques in the world.

ZINC PRODUCTION AT ZAWAR

Zawar (24º21' N; 73º43' E) is located, on the bank of the Tiri River, about 38 km south of Udaipur town in the Aravalli hills in Rajasthan (Fig.). The Aravalli range is composed of rugged yet gorgeous hills of pre-Cambrian metamorphic rocks which also form narrow valleys. These rocks are rich in zinc ore in the form of sphalerite veins in association with galena. Zawar is the only known ancient zinc smelting site in India (Craddock *et al.* 1985). The entire Tiri valley is marked by immense heaps of slag and retorts, which indicate a long tradition of zinc smelting. On some mounds of slag, remains of houses made of used retorts have also been found (see Fig.) as well as stones seeming to belong to the smiths. The mining and smelting activity was not only registered in contemporary local records and literature (e.g., *Nainsi ri Khyat* in 1657; *Bakshikhana Bahi* 91, Rajasthan State Archaives records of Udaipur and Bikaner and others) but also in the writings of several 19th and 20th century scholars, mostly British (Brooke 1850; Burgess 1872; Carsus 1960; Erskine 1908; Shyamal Das 1986 I (originally published in 1886): 305; Tod 1950: 221-222).

The zinc deposits are widely distributed in India, barring the Western Ghats, Nilgiris and Ganga-Yamuna Doab. However, the major deposits are found in Southern Rajasthan, where zinc is generally associated with lead or copper bearing deposits. Zinc (Zn) is generally found in veins in association with galena, chalcopyrite, ironpyrite, silver and cadmium and other sulphide ores (Raghunandan *et al.* 1981). Zinc is used for galvanising iron and steel, brass making, alloying, and in the manufacturing of white pigment in chemicals and medicines. However, in ancient times it was mainly used for brass making.

Mining

Although a lead-zinc deposit recently discovered at Agucha in Bhilwara now makes this site the largest source of such ore, the deposits located in the Zawar area have traditionally been the most well-known and historically significant. At Agucha, extensive mining of rich galena pockets was carried out during the Mauryan times (Tiwari and Kavdia 1984: 84-85). An opencast mine (300m long and 100m wide) at Dariba (Raghunandan *et al.* 1981:86-87) is remarkable. In one of underground mines of the East Load the miners reached a depth of 263 m around 3rd – 4th century BCE (Craddock *et al.* 1989:59; Willies *et al.* 1984). Such mines were rarely known to the ancient world. A ^{14}C date from Dariba indicates that mining had begun in the second half of the second millennium BCE.

This mineralized belt of Zawar extends about 25 km. Major mineralization of sphalerite and galena with varying quantities of pyrite have been found in the form of sheeted zones, veins, stringers and lenticular bodies. Since these minerals are quite distinct, it was possible to separate them manually. This explains why zinc mining and smelting developed only at Zawar.

There are extensive remains of old workings in Zawarmala, Mochia Magra, Balaria, and at Hiran Magra in the form of deep trenches, shafts, open stopes, long serpentine galleries, and inclines. These mines are narrow and vary from 10 to 300 m in length. There is extensive evidence of underground mining too. Sometimes arch shaped pillars (about 4X5m) were left to support the roof while developing mining galleries (Gurjar et al. 2001). Fragments of terracotta globular jars and lamps, wooden baskets, charcoal and ash were also found in and around these mines. Firesetting was the main method for breaking rocks. After fire-setting the rocks were broken with chisels, pick axe, hoes and other iron implements. A few such tools have been discovered from Mochia mines (Craddock *et al.* 1989: 62, pl3). Extensive use of wood work in the form of ladders, roof support, haulage scaffold (^{14}C date: 2350±120 BP) have been found in the mines. For dewatering mines, launders of hollowed timber (3 m long and 20cm wide) were used. These launders have been dated back to 2nd century BCE (Bhatnagar and Gurjar 1989: 6). It appears that this mining continued for several hundred years as indicated by the enormous mound of slag and smelting debris.

Literary Accounts of Zawar Mines

Kautilya's *Arthasastra* (2.12.23, 2.17.14 & 4.1.35) mentions that there was a superintendent of mines in the Mauryan Empire whose duty was to identify metals and establish factories.

While describing silver ores the text clearly mentions that it occurs with *nag* (lead) and *anjan* (zinc). Since there is extensive evidence of mining and smelting of lead, zinc and silver at Zawar, Dariba and Aguchha in Rajasthan, it is quite likely that Kautilya was aware of this activity. Harry (1991) points out that the imperial Maurya series of coins, particularly silver ones, containing one fourth of copper, strongly indicates the mining of silver and zinc from southern Rajasthan. Mining of such ores had surely begun in Rajasthan in the middle of the first millennium BCE, if not earlier.

Perhaps Zawar was known as Aranyakupgiri in the seventh century BCE where deep well shaped mines were also dug. During the medieval times Maharana Laksha Singh (14th century) and Maharana Pratap (16th century) also started mines at Zawar. Abul Fazl in 1596 in *Ain-i-Akbari* records the zinc mines of Zawar.

A few shallow conical and U shaped pits have been found in hard rocks at Baroi and Dariba. They may have been used for crushing/ breaking rock fragments in order to separate the ore. Such pits at Dariba were found close to the large opencast in calc-silicate rock, the diameters of which vary from 8 to 27cm and depth 4 to 18cm

The underground mining of ores at Agucha, Dariba and at Zawar may have been the result of gradual development of mining technology in Southern Rajasthan which was going on since the middle of the fourth millennium BCE when Bronze Age cultures first appeared.

Table 1. Radio Carbon Dates for Zawar Mines (After Gurjar et al.)

BM No.	Context	Material	Date BP	Calibrated dates
BM-2017R	retort	charcoal	modern	1550 to 1635 CE
BM -2065R	retort	charcoal	modern	Modern 760 to 360 BCE
LW/1982/2 BM-2148R	--	wood	2350$\pm$120	285 to 255 BCE
BM- 2149R	LW/1982/1, launder in escape route	wood	2140$\pm$110	365 BCE TO 90 CE
BM -2222R	Trench layer 3	charcoal	240$\pm$110	1510 to 1690 CE or 1730 to 1810 CE or 1925 CE to modern
BM-2223R	Site 30, n side of furnace	charcoal	530$\pm$50	1320 to 1345 CE or 1390 to 1435 CE
BM-2243R	sample 33, site 34	charcoal	350$\pm$130	1420 to 1670 CE
BM- 2484	site 5, layer 3, slag heap	charcoal	100$\pm$45	1695 TO 1730 CE or 1815 to 1920 CE
BM- 2485	site 14, layer 3	charcoal	1950$\pm$60	25 BCE to 115 CE
BM- 2486	site 29, layer 2, small pit or hearth	charcoal	200$\pm$35	1660 to 1675 CE or 1745 to 1800 or 1940 CE to modern
BM- 2487	site 2, trench 2, slag heap	charcoal	1930$\pm$80	40 BCE to 145 CE; 170 to 180 CE

BM- 2488	site 7, trench 2, slag heap	charcoal	1370±80	595 to 720 CE or 740 to 765 CE
BM- 2638	furnace block	charcoal	modern	--
BM- 2639	ZWLW/22, Pratap khan	charcoal	2040±70	160 TO 135 BCE or 125 BCE to 25 CE
BM- 2481	ZM/LW/85/13 small chamber off main galaries	charcoal	modern	modern
BM- 2482	ZM/LW/85/14 short ladder way	wood	2150±110	365 to 100 BCE
BM- 2483	ZM/LW/85/8, burned layer	wood	2180±35	355 to 290 BCE or 250 to 195 BCE
BM-2634	ZWLW/87/26, top chamber	charcoal	1340±100	600 to 790 CE
Balaria				
BM - 2338	support timber western slope	wood (outer ring)	170±50	1660 to 1695 CE or 1725 to 1820 CE or 1860 to 1865 CE, 1920 to modern
BM - 2381	gallery	wood (outer ring)	2360±60	750 to 720 BCE or 525 to 385 BCE
BM- 2666	ZW/LW/87/32	charcoal	390+50	1440 to 1520 CE or 1590 to 1629 CE

Production: Scale and Output

It has been estimated that each retort was filled with one kilogram of charge out of which 400 gram of zinc was likely produced. Each furnace had 36 retorts which were heated for three to five hours and produced around 25 to 30 kg of zinc. It has been estimated that the 600,000 tonnes of smelting debris at Zawar, produced about 32,000 tonnes of metallic zinc in four hundred years (between 1400 and 1800 CE). If we estimate that this level of production lasted from the 12th century to 18th , then the quantity of metal would certainly have been more than 50,000 tonnes.

Colonel Tod in his well known work, *Annals and Antiquities of Rajasthan,* reported that the mines of Mewar were very productive during the eighteenth century, and in the year of 1759 alone the mines earned Rs. 2,22,000 (Tod 1950: 222, 399). Tod writes that about half a century ago these mines were earning Rs three lakh annually. Dariba mines yielded Rs.

80,000. Since no tin deposits have been found in the Mewar region (southern Rajasthan), he appears to be referring to the Zawar mines. The *Imperial Gazetteer of India Provincial Series Rajputana* (1908: 52) cleared any confusion and stated that these mines were famous for silver and zinc and worked on a large scale until 1812-13 when a devestating famine took place (Kachhawaha 1992: 26-27; Malu 1987; Singh 1947).

The production of zinc was certainly at very high levels during the 17th century when Maharana Jagat Singh and Maharana Raj Singh were ruling over Mewar. Local record stated that annual revenues from Zawar were Rs. 2,50,000 and 1,75,002 in 1634-35 CE and 1657 CE respectively. Hence, Zawar was one of the main sources of state revenue. It is also clearly indicated in the records that the per-day income of these mines was Rs. 700. This estimate was later confirmed by the historian Muhnot Nainsi. Another record belonging to the reign of Maharana Raj Singh read that the revenue earned in a year from Zawar was Rs. 17,96,944, though this includes revenue from different economic sectors and industries such as agriculture, trade, mining, and smelting (Bhati 1995: 1,2,11,12, 14). Gurjar (et al.…: 634) have examined an account book dated 1655 CE belonging to the same king which is preserved in the State Archaives, Udaipur. It was recorded that Zawar earned Rs. 1,70,967 a single month! I am, however, not sure whether this income was obtained from mining and smelting only. Erskine states that these mines were certainly an important source of income from the 14th to the early 19th century since they earned more than two lakh rupees in annual revenue for Maharana's treasury at least until 1766. Zawar was also likely an important trade centre between the 12th and early 19th century CE due to large scale production of zinc.

Local records, as discussed above, clearly indicate that Zawar was one of the main sources of revenue for the royal treasury between the 14th and early 19th centuries. Traditionally it is believed that Maharana Lakha, who was ruling in the last quarter of the 14th century, had the mines re-opened. He might have opened several new mines instead of reopening the old ones for large scale production. The best evidence of dating comes from the discovery of a coin hoard found in a clay pot by Gurjar in 1984 at old Zawar. The Akbar-era coins were found in mint condition. In other words, radiocarbon dates assigned the industrial scale smelting of zinc to the period between 12th and 19th century (Craddock *et al.* 1989:48).

It is believed political instability in Mewar, frequent attacks of the Mughals, Pindaris and the Marathas, and recurrent famines in the 18th century contributed to the gradual abandonment of these mines.

Mining of several ores such as iron, copper, lead was being done as late as the 19th century in several parts of Rajasthan. Unfortunately, the Zawar zinc operation came to a halt around 1812 CE. This is in contrast with Chinese traditional smelting which did not experience a similar decline. A few British officers attempted to restart these mines in the middle and late nineteenth century with the financial support of Maharana Sarup Singh (1842-61), Shambhu Singh (1861-1874 CE) and Sajjan Singh (1874-1884 CE), but failed.

CONCLUSION

Though early evidence of metallic zinc is known from Athenian Agora and Taxila between 4th and 2nd century BCE, there is no evidence of regular production of metallic zinc. The first evidence of pure zinc comes from Zawar as early as 9th century CE, when a distillation process was employed to obtain metallic zinc. Thus the Zawar metallurgists brought about a breakthrough in non-ferrous metal extraction around 12th century, if not earlier, by producing it on commercial scale. In China, commercial production of zinc started almost three hundred years later than India. It appears that brass was introduced in China in the early centuries of the Common Era through Buddhism, though the idea of zinc distillation process traveled in 16th century via interenational trade to China. From China it was exported to Europe from the middle of the 17th century CE under the name *totamu* or *tutenag,* which was derived from *Tutthanaga* - a name of zinc in South Indian languages. However, Indian zinc had already reached Europe prior to this and had created great curiosity about the new metal. Therefore, Zawar had globally stolen the march by becoming the oldest commercial center of zinc in the world. William Champion's furnace in the 18th century at Bristol was based on Indian downward distillation process, the idea of which may have reached there through the Portuguese or East India Company. Hence Zawar, in the words of Craddock, is the ancestor of all zinc production techniques of the world. It was an industrial activity which laid the basis of various modern chemical and extractive industries.

Ch 9

HIMALAYAN DOMESTIC ARCHITECTURE
(WITH SPECIAL REFERENCE TO THE WESTERN HIMALAYAN REGION)

By O.C. Handa

Introduction: The Evolution of Man and his Dwellings

Shelter, food, and clothing have been the prime necessities of man since civilization began. These three necessities have been the foolproof benchmarks of man's evolution from the primitive cave-shelters to the skyscrapers of our times. While essentially nothing has changed in the process regarding food and clothing (man eats the same tubers, fruits, vegetables, grains and meats and clothes himself with the same animal and vegetal fibres even today that he did ages ago), man has been insistently improving upon his dwellings through the passage of time. Mankind has developed his dwellings to be convenient and comfortable under ever-changing lifestyle and environmental conditions. In this ongoing evolution, not only the basic materials of building construction and the technique of construction have changed radically, but the planning and design parameters, functional imperatives and other design considerations have undergone complete transformation.

On a more sublime level, living in the self-created microenvironment within the four walls of his dwelling, man has isolated himself from his surroundings. He has not only created a gulf between himself and the Nature, but today he even dares to challenge it, and in that craze, occasionally falls in its inescapable traps. To harness Nature in a symbiotic and complementary manner is one thing and to 'manage' it with man-centric psychology is another, to which the man seems to be falling headlong into. Consequently, he finds himself at the loss of his mooring with the Nature. In this age of popular resurgence, the paradox of modern civilization is that omnipresent notions of modernity have so completely strangled our objective and rational thinking that we have developed a callous attitude towards our traditional wisdom and the inherited value-system. In the language of today's ideas of modernity, these traditional systems of knowledge have made the mistake of identifying us with Nature and have thus been deemed primitive. In our currently benumbed state, we tend to fall in the quagmire of the influential consumerist mafia. Today, everything to sustain us is conveniently available 'readymade' in synthetic capsules. Thus, alienated from our roots and detached from the Earth, man is as helpless and desperate today as he ever had been. He is too incapacitated to differentiate between the fallacies of the 'synthetic living' and the subtleties of the 'natural living'.

The Need to Re-examine Traditional Knowledge

Therefore, there is dire need to wake mankind from its stupor and make him conscious of his roots and surrounding before it is too late to redeem. As a Biblical dictum tells, “Go unto the rocks whence we have sprung”. It is time for us to realize it and look for the nuggets of traditional wisdom that lay scattered among the rural folks and find out their relevance in the modern context. In our times, when fundamental studies related to the environment and the common people are being encouraged, it becomes imperative that the so-far ignored and under-evaluated wealth of traditional wisdom is explored and redefined in the contemporary scenario for the betterment of the Earth and Man. The study of the Himalayan Domestic Architecture (with special reference to the Western Himalayan region) is a humble effort towards that end. This study is essentially directed to explore those surviving nuggets of traditional wisdom, which, through ages, have provided people with the most cost-effective, aesthetic, congenial and eco-friendly dwellings in the mountainous Western Himalayan region.

The Western Himalayan Region

The vast Himalayan expanse west of the Yamuna, composed of diverse mountainous features and different geo-climatic conditions, has commonly been known as the Western Himalayan region. Geographically, the Indus defines this region to the west. The spiny ridges and silvery peaks of the trans-Himalayan Karakoram Range on the north and the northeast separate it from the Central Asian highlands and the Tibetan plateau, respectively. Towards the east, the Yamuna forms a natural border between this Western region and the Central Himalayan region in Uttaranchal. To the south, the undulating foothills of the Siwaliks broadly define its border with the Indo-Gangetic plains of the Punjab, Haryana and the western Uttar Pradesh.

Administratively the Western Himalayan region within the Indian territory is divided into three states. These include Jammu & Kashmir, Himachal Pradesh and a small part of Uttaranchal. Despite the politico-administrative divisions, the entire Western Himalayan region has a very long and common history and a coherent socio-cultural, religious and economic background. This phylogenetic relationship is profoundly reflected not only on various temperamental, ideological and behavioural aspects of the people of this region, but in the art and architectural traditions as well. Nevertheless, distinctive quintessential and local characteristics may also be identified here in the ethos of these people living under different localised geo-climatic conditions in different terrains and valley-areas.

All these factors have overwhelmingly influenced the architectural peculiarities, planning imperatives and functional aspects of residential houses and rendered to them distinct local characteristics. Broadly, the entire Western Himalayan region may be identified into three distinct geo-climatic zones running longitudinally from the southwest towards the northeast. These are: (1) the Sub Himalayan zone, (2) the Mid-Himalayan zone and (3) the Trans-Himalayan zone.

(1) The Sub Himalayan Zone:

The southern slopes of the Outer Himalayan Mountain ranges, which slope down southwards to the edge of the Punjab plains forming an undulating profile, is the Sub Himalayan zone, or the *tarai* belt. Traditionally, this area has remained populated by agrarian communities such as the Kunets in the *doons* and the Khashias in the trans-Giri area of Sirmaur district and Jaunsar-Bawar area of Uttaranchal. However, after the Anglo-Gurkha War, many Jat families also settled in this area. After independence, many Muslims also settled in this belt. Thus, the demographic pattern of this sub hill region has changed significantly.

Architectural Characteristics Reflect The Region

In this south-facing zone, the climate largely remains temperate and humid. Therefore, to keep the interiors protected from the sun and storm showers, deep fronting verandas and extended roof-projections are provided. One may find extensive use of stone for the walls as well as fine slate used to cover the slanted roofs. This observation holds good more for the sub-mountainous Kangra area and most of the *tarai* belt. Residential houses in this area are, as a rule, double storied. However, in tracts such as the *doon* belt where the climate is hot and dry, one may find thick stone-made walls in single storied dwellings. In these houses, even the fronting verandas are completely closed and look more like wide corridors. The flat roofs of these houses are made of rammed impervious clay that keeps the interiors dry and insulated from the rains, which, of course, is scanty here.

In some instances, depending upon the local conditions, the back walls of the houses are allowed to abut on the hill profile. These houses, locally called the *darabas*, give the illusion that they are emerging out of the mountain slope as an organic part. The back rooms of such house are pleasantly cool even during the severest summer months. Since, the rain is moderate and the ground profile flatter in the *doon* belt, the houses here typically spread horizontally rather than vertically. While the houses in the lower valley areas are as good as the *darabas*, higher up on the mountain slopes, where the flat stretches are uncommon, the houses are double storied, with increased use of wood.

Locally Available Resources Influence Building Characteristics

In the entire sub-Himalayan zone, large and dense forested areas are rare, with the exception of the *sal* wood belt east of the Markanda River and thin *chir* forests to the west of it. While *sal* has a very limited possibility as structural timber, the *chir*, due to its resinous content, is completely ruled out for the structural use. Understandably, use of wood in this belt is minimal, and is generally restricted to doors and windows. In the Kangra area, where even *sal* is not available, people have been using local species, such as *tun, khirak*, *tali*, etc. with the sparse use of deodar, which they procure from the forests of the Dhauladhar.

The slopes of Dhauladhar also have some of the best quarries of fine slates, especially the side-valleys which provide the highest quality fine-grained blue sandstone. The fact that the colossal monolith images of Kuber on the front gate of the Reserve Bank of India Building in New Delhi is made of a one-piece stone block quarried from a place near Baijnath in Kangra

gives testament to the quality of the stone found in the region. It is because of the abundance of good quality structural stone in the sub-mountainous belt that one finds extensive use of it in the secular and religious buildings in this area. Some of the finest traditional stone-carvers and masons may be found in this region, especially in the Jammu and Kangra areas. The Kangra area is known for high precipitation. Therefore, most of the houses here are double-storied.

(2) The Mid-Himalayan Zone

The wide geographical terrain between the Outer Himalaya Range and the Great Himalaya Range may broadly be defined as the mid-Himalayan zone. This region is populated by a heterogeneous amalgam of various ethnic communities. Among them, the Gujjars, the Gaddis and the Khashas are the most prominent. Among these, the Khasha form the overwhelming majority since even the earliest times. The mainstay of Khasha economy has been agriculture. However, pastoral vocations, like goat and sheep breeding, cattle herding, etc. have also been their major supplementary vocations. Since, wood-based domestic and religious architecture is largely patronised by the Khasha majority and confined to the area where the Khasha population predominates, the wood-based architecture of the Western Himalayan region may reasonably be defined as the Khasha Architecture. Nevertheless, deviation from this rule may be noted under different occupational considerations. For instance, because of the nomadic vocation of the Gujjars, their rustic mud-build houses are known as the *myharas.* Similarly, the Churahi and Pangwal houses, although at times double storied, are externally not much different from the *darabas.* Internally, these are all-in-one single room units, in which the animals and the humans live together around a central fire-range.

The Rich Forests of the Region Influence Architecture

In this middle region, where the climate remains salubrious almost throughout the year, most of the villages are located in the sunny valleys and on the mountain spurs. One may find excessive use of wood in the house building. This tract roughly includes the northern part of the Jammu area of Jammu & Kashmir, southern part of the Chamba district, Mandi, Kullu and Shimla districts and trans-Giri part of Sirmaur district in Himachal Pradesh, and Jaunsar-Bawar area of Dehradun district in Uttaranchal.

This area is rich in the variety of temperate forests. The lower heights contain conifers and broad-leaved trees, succeeded by the alpine growth of oaks and conifers higher up where the mountain slopes are richly covered with high quality *deodar* trees. These forests have provided an inexhaustible supply of quality timber for building construction, extending from the floor of the valley to an average height of 3350 metres. Since wood has been abundantly available in this region, most of the houses and temples here are lavishly made of wood from bottom to top. Also, the availability of quality wood in the region has led to the flourishing of the art of woodcarving here.

However, good quality structural stone is rarely available in this region. All that is available from the stone quarries is slate schist laden with mica. It can only be sliced into thin slates. These slates have been the most common roof-covering material in vernacular houses. This schist stone is inferior for structural purpose, for neither can it be dressed or chiselled into blocks, nor does any type of mortar stick to it. The only way to use it is to lay it flat one over the other in irregular courses without any binding mortar. Obviously, it is unsuitable for the structural purpose.

Unique Building Techniques of Mid-Himalayan Zone

Given the abundance of wood, the hereditary local artisans have devised an ingenious way of using the slate stone found in the region for the structural purposes in a unique integrating technique. They use the stone between the sturdy wooden wall plates which are framed together.

It is possible that before the technique of combining wood and stone for wall construction was developed by the artisans in the Western Himalayan interiors, all residential houses were made of wood. That fact is well established from some of the completely wood-made residential houses in the interiors of Mandi, Kullu, Shimla and Kinnaur districts. With the abundance of quality timber from the coniferous *deodar* jungles and the inherited expertise to handle wood in diverse manners, the traditional artisans could hardly think of economising its use. Possibly, the over exploitation of the precious *deodar* jungles might have necessitated economy in the used of wood for the residential houses.

Therefore, the local traditional artisans devised techniques of combining wood and stone together for construction purposes. They developed these techniques so as to ensure uniform distribution of the superimposed load, solidity of wall and lateral stability. In this construction technology, wood and stone are used in different combinations depending upon the height and function of the structure. The most common of such wall-types has popularly been known as the *katth-kuni,* i.e., the timber-bonded wall with the alternating courses of wood and stone. When the use of wood for constructing walls is to be minimised, the walls are raised with the wooden wall plates and are vertically widely spaced with a number of courses of stone between them. Usually, the high-raised solid stone plinth of tower-type structures are made in this way. Such walls are known as *dhol-maide* in the Kullu area. In Chamba and other places in the interiors where excessive use of wood is not affordable for constructing a house, the *katth-kuni* technique has been slightly modified by replacing the square-cut massive wooden wall-beams with thick wooden planks placed on edge to define the thickness of the wall. Thus, a box-like space is formed within the plank 'walling'. The space between the 'walling' is then hand-packed with stones. This type of wall is called as the *farque* in Chamba.

(3) The Trans-Himalayan Zone

Situated to the northeast of the Great Himalayan Ranges and spread over the Ladakh region of Jammu & Kashmir and the Lahul & Spiti and upper Kinnaur area of Himachal Pradesh, the trans-Himalayan highland region forms a distinct class of its own. Here, neither the land nor the sky is anything like what most of us are used to. It is one of the most elevated regions on the earth 'possessed of a necklace of radiant snow mountains.' High altitude, climatic isolation and the blinding glare of the snow and ice deposits on the ranges have produced one of the harshest living conditions on earth.

The Mongoloid Sino-Tibetan speaking inhabitants of this region, known as the Kiratas in the latter Vedic literature, are known to have occupied this tract around the middle of first millennium BCE. Besides the Kiratas, the other indigenous communities of this region are the Mons, the Dards, the Hunjas, the Drokpas and the Buchhens. The ethnic distinctions notwithstanding, all the inhabitants of the trans-Himalayan snow-desert are the ardent followers of the Tibetan form of Buddhism.

Harsh Conditions Make for Unique Architecture

Because of the dry and cold climatic conditions in the trans-Himalayan wilderness, there has been almost total absence of any type of cognizable vegetation in Ladakh, Spiti, upper Kinnaur and part of Lahul. .

The limited choice of building construction material and prevailing geo-climatic compulsions have been the deciding factors for the type of domestic architecture in this unearthly region. Because of the harsh climatic conditions in the region, mud is advantageously used as the bonding and building construction material right from the erection of walls to the covering of roofs. Thus, the building construction technique that have developed in this region is essentially the mud-based. Since mud has limited architectural possibilities, the residential houses as well as the monasteries of this zone are box-like structures. Due to the extremely cold climatic conditions, openings to the outside are minimized so that the interiors may be kept warmer with the use of minimal fuel. The mud built box-like houses of this region blend so inextricably with the surrounding bareness that it may even go unnoticed while looking down from a high peak or from the sky.   Also used in construction are roughly hewn schist stones and very scarce and unavoidable use of wood

Characteristics of Trans-Himalayan Zone Housing

The walls of the houses are made of sun-dried large-sized mud bricks. Sometimes, well-kneaded mud is stamped between the shuttering of the rough wooden planks, while other times woven willow twigs are used. In that manner, the wall is raised layer by layer. Where stone is easily available, it is also mixed into the mud in the *in situ* process. At times, larger random stones are also used for raising walls. In that case, mud is used as the bonding agent. The outer faces of the *in situ* mud walls of the residential houses as well as monasteries may at times have wider bases, which become tapered topwards. This innovation imparts stability to these multi-storied structures.

Because of the extreme paucity of timber, the larger rooms are divided into squares or rectangular sectors by erecting wooden posts. The roofing beams and joists are spanned across these posts. Planks or twigs are placed over the joists, over which birch sheets are spread followed by thick layers of stiff clay. Sometimes, depending upon availability, a special type of clay, called *markula*, which is known to possess excellent waterproofing and bonding quality, is used for that purpose.

In the trans-Himalayan area of Ladakh, Lahul & Spiti and the Upper Kinnaur, the houses are generally double storied or more. Located on the tablelands in the valleys or on the convenient mountain ledges, most of the houses here are in clusters. The ground floor of the home is typically used for keeping cattle and storage of fodder etc, while the upper floors are used for living. The approach to the upper floors is always from the room in the ground floor. Rarely one finds an open and external approach to the upper floors. On the upper living floors, open terraces are also provided for sitting under the sun during the chilling winter months. The rooms, though spacious, are normally without windows, and where these are provided, care is taken to orient them to the sunny side and keep them small in size.

Environment as a Factor in Design Imperatives

The construction and design aspects of houses of the Western Himalayan region are largely regulated by the local topographical and environmental factors, the availability of construction material within the locality and the edict of the village deity. The number of floors in the house is also decided on these considerations. Sociological and economic factors also influence that consideration. For instance, in the sub mountainous region in the *doon*, the houses are generally single storied since ample flat area is available around for the houses to stretch horizontally. Most of the people in this area are agrarian folks and most of their activities are earth-bound. Therefore, the single storey houses are convenient for them.

However, in the Kangra area where rainfall is normally heavy, the climate remains humid for most part of the year. Therefore, the people there prefer double storied dwellings, with most of the living area on the upper floors and the sundry storage, etc. on the ground floor. However, economic factors also play a role in deciding the number of floors. Most of the houses of the people belonging to the low-income group are single storied. In this belt, there are certain pockets where neither timber nor stone is economically available. In such places, even bamboo is used for building houses. Such houses can be the single storied double storied units. In the dry and hot area on the border of Hamirpur, Bilaspur and Mandi districts, such houses are common. In this area, drinking water has been extremely scarce. The people have devised ways to tap underground water in the deep wells, called *khatis*. Each household has its own *khati*, which is kept locked and secured against theft. The houses in this sub-mountainous belt are generally in clusters.

In the mid-Himalayan zone where the houses are on spurs or along mountain slopes, people chose to build homes in the linear formation on different terraces along the contours. Such

houses normally face the valley. However, wherever large flat patches are available on the spurs or in the valley, houses in clusters may also be seen. Because of the steep ground profile, it may not be possible for the houses to expand horizontally. Under that constraint, these sore skywards with multiple stories.

Since open space around houses is scarce in this area, care is taken to leave ample open space in front of the house for performing various agrarian chores. For that purpose, large circular open spaces are earmarked. This space is paved with large flagstones. This open space is called the *khawala*, i.e., the *khalihan.* The *khawala* is a multipurpose secure open space, in which grains are thrashed, winnowed and allowed to dry in the sun.

While the singly-storey house may be a rarity in this mid-Himalayan region, the double-storey house is common. Affluent people may even have three or more storied homes. Such multi-storied houses are common in the lower Kinnaur, but are rare elsewhere in this region. While, the ground floor of these houses is used as the byre and the fuel and fodder store, the upper floors are generally residential.

Wood Joinery of the Region

One of the most noteworthy aspects of the domestic architecture of this region has been the technique of joinery in woodwork. The traditional *baddis* or the *tarkhans* can erect a complete house made completely out of wood without using even a single iron nail to join different members. Whenever it is felt necessary to use a nail to strengthen a joint, as in case of the door-shutters, bamboo nails are used. Nails are only used in fixing the slates to the purlins on the roof. Earlier, even when wooden planks were also used as roof covering, the use of nails was avoided.

Interestingly, local traditional artisans did fabricate trusses, struts or a diagonals to secure lateral rigidity in the roofing sub-structure. Instead, they employed an age-old method of supporting the roof-rafters on the wooden pillars, posts or walls. The same age-old method has continued even today in the residential houses. The roof is projected considerably beyond the supports to protect the wooden exterior of the building from the direct effect of sun and rain. The window openings, balustrades and other exposed structural parts are carved meticulously and elaborately.

Beyond Housing: Himalayan Kathiars

Besides residential houses, one can may also enounter *kathiars* (greeneries) once belonging to the landed aristocracy and the castle of the local barons. These edifices of the medieval past are now almost dysfunctional, yet are helpful in understanding the medieval socio-economic structure of the area. They are equally helpful in the research of the planning parameters of the traditional villages and their inherent organic symbiotic integrity. The stratified yet coherent layout of Nirmand located deep in the Kurpan valley – the most

ancient and one of the largest villages in the entire Himalayan region, having epigraphic evidence of its existence in the 7th - 8th century may be cited as an example.

Ch 10
SUSTAINING THE ANCIENT TANK HYDROLOGY – THE CASE OF TAMIL NADU STATE, INDIA

K.PALANISAMI

ABSTRACT

Tank irrigation systems of India

Tank irrigation contributes significantly to agricultural production in parts of South and Southeast Asia. Especially in South India and Sri Lanka, tank irrigation has a long history that continues till today. Many currently used tanks were constructed in the past centuries. They account for more than one-third of the total irrigated area in Andhra Pradesh, Karnataka and Tamil Nadu states. The tank irrigation system has a special significance to the marginal and small scale farmers who make up the majority of agriculturalists. They essentially depend on tank irrigation for water since they are less capital-intensive and have wider geographical distribution than large projects (Palanisami, 2000).

An irrigation tank is a small reservoir constructed across the slope of a valley to catch and store water during rainy seasons to be used for irrigation during dry seasons. Tank irrigation systems also act as an alternative to pump projects, where energy availability, energy cost or ground-water supplies act as constraints. The distribution of tanks was quite dense in some areas. However, over years the performance of the tanks has been declining.

Tank use in India: How much and by who?

The share of tank-irrigated area in India has declined from 16.51 percent in 1952-53 to 5.18 percent in 1999-2000, whereas the share of groundwater irrigation has increased from 30.17 percent to 55.36 percent during this same period. The share of the tank-irrigated area to net irrigated area (NIA) has been declining continuously over the years (Fig 1) Among the three major sources of irrigation, tank-irrigated area is the only one that has been declining continuously since the early seventies. Many argue that the area under tank irrigation started declining only after the introduction of the green revolution. Furthermore, among the states in India, the area under tank irrigation has declined most drastically in those states where tank irrigated area accounts for a relatively large share in the net irrigated area. It has increased marginally in certain states where it accounts for very low share in the net irrigated area.

Data from the Agricultural Census of India for five time points, namely 1970-71, 1976-77, 1980-81, 1985-86 and 1990-9, indicated that the resource poor farmers (owning less than 2 hectares) still account for major share of tank-irrigated area in India. Marginal (less than 1 ha.) and small farmers (1-2 ha) together accounted for about 40 percent of tank-irrigated area in 1970-71, which further increased to nearly 55 percent in 1990-91 thus accounting for nearly two third of tank irrigated area. On the other hand, the share of tank irrigated area used by large farmers declined from 13.59 percent to 6.02 percent during this period. Since the farmers belonging to marginal and small size group are mostly poor, they could not afford cost-intensive irrigation sources like groundwater as in the case of medium and large farmers. This is why tank irrigation continues to play a crucial role among small and marginal farmers even today. This is also true across different states where tank irrigation has considerable presence even today (Narayanamoorthy, 2004).

Tank systems of Tamil Nadu

Southern parts of India are noted for the intensity of tank usage. Unlike the northern region, the rivers in the south are mostly seasonal and the plains are not extensive. Further, the geology is not favorable for groundwater storage. The local topographic variations have been effectively exploited to impound rainfall in tanks which are used to raise irrigated rice crop and simultaneously serve as a means of improving groundwater recharge in their command areas. There are about 127,000 tanks in the southern region consisting of Andhra Pradesh, Tamil Nadu and Karnataka states (Agarwal and Narain, 1997).

This tradition of tanks as the largest source of irrigation continued until mid 1960s. The decline of tank irrigation was due to the constitution of policy which had its origins in the very early phase of British rule in India. An impression was created that the smaller irrigation works were uneconomical and unnecessary burden on revenue officials because of changes in the tenurial system towards raiyatwari or Zamindari.

Among the southern state, Tamil Nadu state alone has about 39,200 tanks with varying sizes and types. The tanks are classified into system tanks (which receive supplemental water from major streams or reservoirs in addition to the yield of their own catchment area) and non-system/rainfed tanks which depend on the rainfall in their own catchment area and are not connected to major streams or reservoirs. The tanks are also classified into Panchayat Union (PU), Public Works Department (PWD) and *Ex-zamin* tanks based upon the management authority. Panchayat Union tanks have a command area less than 40 ha, and are under the control of village communities. Those tanks having a command area more than 40 ha as well as all the system tanks are maintained by PWD. *Ex-Zamin* tanks were constructed by *zamindars* (landlords) during the British administration. After abolishment of *zamindari* system by the State government in 1957, they were transferred to Panchayat Union and PWD based upon the sizes of command areas. Out of the total of 39,200 tanks in the State, 53 per cent are PU tanks, 22 per cent are PWD tanks and 25 per cent are ex-*zamin* tanks (Table 1)**.** There are about 9,800 *ex-zamin tanks*, of which more than 60 per cent are concentrated in the undivided Ramanathapuram district (Palanisami *et al*, 1997).

Management of Tanks

In the ancient days, tanks were considered to be the property of rulers. The farmers paid a portion of their produce to the ruler. Farmers also were in charge of the maintenance of the tanks, and supply channels. Zamindars ensured the proper maintenance of the tanks, and channels, since they reaped the benefits of farming in large areas. However, when the British introduced the ryotwari system in 1886, tanks with an ayacut of 40 ha and above were brought under the control of PWD and smaller tanks were under the administrative control of local bodies, or vested with the villagers themselves. Since the local bodies did not have qualified engineers and the duties of the ayacutdars were not clearly mentioned, the system of self-maintenance by the farmers, known as *kudimaramath* works, slowly declined. Tanks were silted up, and supply and distribution channels choked. The deterioration of the tank irrigation system has been a subject of considerable discussion, at least since the middle of the 19th century. The Report of the Public Works Commission of 1852 stated that there was not much of voluntary community labour involved in tank maintenance, and it reported that in all districts labour was more or less forced to work. In fact an act was passed, namely the Madras Compulsory Labour Act of 1858 (or what is known as the *Kudimaramath* Act), with a view to legalising compulsory labour for certain aspects of maintenance, and also to penalize the non-performance of *kudimaramath* labour. The entire administration of the act of levying and collection of fines was left with the irrigation panchayats. The Famine Commission of 1878 brought to light quite forcefully the deteriorating conditions of tanks and advocated a systematic policy of maintenance. One of the most important recommendations of the commission was the creation of tank restoration parties (Palanisami, 2000).

However, at present the responsibilities are shared between different institutions which are also inconsistent from state to state (Table.2)**.** In all the states, the local village is responsible for water distribution and management of the tanks with a command area of below 40 ha. In spite of these institutions on tank management, the performance of the tanks continues to be reduced over years.

Tank hydrology

Tank hydrology is an integrated component in the management of the tanks and their performance. Tank hydrology affects various hydrological behaviours such as floods and droughts over time. The components that control tank hydrology are such that they can be easily managed even by the local community. The lessons from the ancient tank hydrology are, therefore, still very useful in framing future investments in tanks. What follows is a brief description of the various components of the tank hydrology.

Generally a catchment is classified into one of three categories depending on water absorption characteristics of the soil which are, in turn, dependent on geological formation and slope. Hilly tracks, where run-off is high, are classified as good; catchments with alluvial and red soils where the absorption rate is moderate are designated as average or moderate; catchments with porous sandy soils where the absorption rate is high are designated as poor. For the same amount of rainfall, these three types of catchment will generate quite different levels of runoff.

Another classification, normally used by PWD in calculating tank water yields, involves the geographic relationship between the catchment area and the tank water spread. An empirical formula has been developed by PWD to estimate the tank yield based on the "Strange" Table. The water yield or run-off from the rainfall for any given tank is a function of the geographic area and the type of the catchment, i.e., whether the tank is isolated or connected to a group of tanks, or to an adjoining stream or river. Tanks located in the lower reaches of a drainage basin or valley will have the advantage of receiving surplus water from upper tanks in addition to the run-off from their own catchment areas during the rainy season. Lower tanks do not receive all the run-off from upper catchment areas because the upper tanks intercept this water. However, a portion of the run-off from upper catchments usually flows down to the lower tanks. These upper catchments with tanks are designated as intercepted catchments. An empirical assumption has been made and a relationship has been developed to estimate the water yield from an intercepted catchment to a lower tank. It is assumed that 20% of the run-off from an intercepted catchment flows down to the lower tank.

The water movement depends on the location of the tanks in a tank series or chain. Assume A, B, and C are three tanks in a series. A and B are the upper tanks and C is the lower tank. Area 1 is the free catchment of tank C, while the areas denoted as 2 and 3 are the free catchments of tanks A and B. The yield for tank C is computed by calculating the total yield of the free catchment in area 1 and adding 20% of the yield from the catchments in areas 2 and 3. Twenty percent, or 1/5 of the catchment area of an upper tank is known as the "equivalent catchment." Free catchment (a) + equivalent catchment (b) = combined catchment for a tank.

Yet another source of water supply for tanks is the diversion of water from a stream or reservoir. This is the criteria which divides tanks into system and non-system tanks. Most system tanks have a greater reliability of water supply provided by larger reservoirs. In contrast, non-system tanks are, at best, connected to a stream and receive water whenever there are adequate flows in the stream, usually during the monsoon months.

Although rivers or streams help to provide additional water, they do not ensure the reliability of water supply that is afforded by a system tank. The PWD computes the water yield from supply channels based on certain empirical assumptions such as the number of days the supply channel can deliver water to the tank in a year. This may also vary from year to year in accordance with the intensity of rainfall, the number of rainy days, and other catchment characteristics. Generally the PWD assumes a 10 to 15 day supply through the supply channels from rivers or streams in non-system tanks.

The total number of tank fillings is then calculated by dividing the total yield from the three sources by the storage capacity of the tank. For example, if the water yield available for a tank from the above three sources is 20 mm^3 and the storage capacity of the tank is 8.2 mm^3, then the number of fillings =Yield /Capacity = 20/8.2 = 2.4

Tank Structural Components

A typical tank irrigation system consists of the following components: surplusing arrangements, feeder canals, tank water spread area, tank bunds, sluices, and distribution system (main canals, field channels).

A. Dispersal of Excess Water

The difference in capacity between the sill level of a sluice and the full tank level (FTL) is the amount of water available to irrigate crops. For tank safety, provisions are necessary to dispose any water in excess of what a tank can safely hold for future use. Structural arrangements designed to serve this function can be categorized as follows: (i) natural ground escape and breaching mechanisms, (ii) surplus weirs, and (iii) calingulah.

B. Feeder Canals

These canals come from the catchment areas and usually run only 0.3 km to 3 km in length before joining the water spread area of the tank. In most cases, the feeder canals have become filled with silt and abandoned. Encroachment and extension of villages due to population pressure and poor maintenance of the canals have also reduced their length and capacity. Abuse of the catchment and supply channels has reduced run-off in many tanks. Over a period of time, this has resulted in lower tank water supplies. Siltation and encroachment have had a more deleterious impact on non-system tanks than on system tanks. Since system tanks receive water regularly, they can better meet water demand, even with encroachment, by drawing water from reservoir storage.

C. Tank water spread area

This is the area where water is stored. For most of the tanks, the ratio of water spread to command area varies from 1:4 to 1:8. For every ha. of the water spread, there will be approximately 4 to 8 ha. of command area. Since the water supply is erratic, water spread area will be dry in some years especially in non-system tanks.

D. Tank Embankment

These earthen bunds or levees are normally U-shaped with greater height at the center and a gradual reduction in height at both of the flanks. The tank bund is usually extended enough so that the water stored in the tank does not escape at the flanks when the tank is full. Normally the bunds are 1 to 3 m wide at the top depending on location thus facilitating the transport of silt away from the tank by bullock-carts. Heights vary from 4 m to 1 m. The cost of the bund is a major component in tank construction, amounting to about 46 percent of the total cost. Currently, the condition of many bunds is poor due to erosion caused by wave action. Also, in several instances, the height has been reduced due to regular use of the bunds by bullock carts and other modes of transport.

E. Tank Outlets

In most cases, tank water is drawn by gravity. The number of sluices vary depending upon the location of the tank and the topography. Normally there are 2 to 4 sluices. There are upper and lower sluices, depending upon their capacity to draw water from the tank. Normally the lower sluices are located in the middle or deeper portion of the tank and can draw more water over a longer period of time. The upper sluices, located at a slightly higher level, draw water when the water level in the tank is adequate. As the water level drops, the sluices will draw less water and in some cases the sluices do not function since the water level is too low. The inequity in the amount of water that can be drawn from the variable-height sluices may lead to mixed crop patterns indicating the differences in water availability. Water intensive crops are found in the area served by lower sluices while less water intensive crops are found in areas served by the upper or high level sluices.

F. Distribution system

A tank's distribution system consists of the main canal, distributaries, and field channels. The main canal generally ranges in length from 0.5 km to 4 km and irrigates from 20 ha. to more than 200 ha. The length of canals and the area irrigated varies widely. Distribution networks and their performance depend upon the terrain and the slope of individual command areas. Different designs were adopted depending on what distribution arrangements best suited local conditions. Maintenance of the main canal, distributaries, and field channels is the responsibility of area farmers. In cases where the main channel is severely damaged (due to breaches), the PWD will assist farmers with repairs. Since the entire distribution system is usually unlined, water losses are high and water is not distributed equitably

among head and tail-end farmers. In some cases, the canals are so wide and the drainage conditions so poor that the excess water reduces crop yields, particularly in areas near the head of the canals.

Relationship between storage, area irrigated and length of embankment

The relationship between the storage capacity, area irrigated, and bund or levee length depends on the local terrain. Tanks located in steep valleys will have steep bunds and deeper storage while tanks located in a flatter terrain will have long bunds and shallow storage. The length of the levee per unit of water stored generally decreases as the tank size increases, indicating that larger tanks generally have higher levees. In a few exceptional cases where land is readily available, large tanks are shallow with long levees. Normally, the ratio of command area to water spread area is lower in smaller tanks compared to large tanks. In the case of smaller tanks, the ratio of command area (C.A.) to water spread area (W.S.A.) is normally C.A./W.S.A. = 2. In larger tanks, the ratio is 4 to 6. This ratio is significant because the larger the water spread area, the greater the opportunities for encroachment as well as the area taken out of production for water storage.

The storage capacity of the tank and the number of fillings in the season generally indicate the success or failure of tank irrigation. Since the storage capacity multiplied by the number of fillings gives the total water storage and since the command area design is based on total storage capacity, the total storage capacity of the tank per unit of the command area is assumed to be constant across tanks. The area irrigated is based on the assumption that one mm^3 will irrigate 85.8 ha. In general, the water to be stored per hectare of command area is about 1.0 to 1.2 cubic meters of water, since this is the water requirement for rice during the crop season.

One major problem with the number of tank fillings is that the additional fillings may be realized only after the first filling is exhausted. Any delays or failure in getting the additional water can damage the standing rice crop. For example, if the number of fillings is two, the farmers will plant the rice based on the first tank filling and then plan on the second tank filling to allow the crop to fully mature. However, this is highly risky considering the fact that if the rains fail during the later part of the monsoon, the tank will not receive the anticipated second replenishment. Farmers generally do not have an information system except past personal experience that can help them asses the probability of rains in advance. In the case of a tank which requires only one filling, the risk factors are lower since farmers are able to assess the amount of available water before planting.

Tank hydrology and performance of tanks over years

A tank's irrigated area depends on the rainfall received and, hence, the number of fillings in a season**.** Within a 10-year period, the tank gets three years of normal supply, five

years of deficit supply and two year of complete failure (Table 3). Given rainfall uncertainties, the tank performance is observed to decline over years.

A variety of problems arise with the use of tanks that add to this steady decline in performance. Obviously above-outlet problems such as poorly maintained structures (bunds, surplus weirs) exist. However, mismanagement also contributes to the problem. For example, forest land adjacent to some catchment areas has been re-zoned for human settlement by the Government through local pressure. Also, there are severe encroachments in the tank foreshores. Siltation of the tankbed is a known problem and is believed to reduce water storage capacity about 20 to 30 percent. In regards to below-outlet problems, the most common problem is that channels are not maintained and become broken resulting in heavy water losses.

Well irrigation has dominated tank irrigation in several cases. Some places have witnessed an increase in the number of wells in areas that had previously been under tank command. This is an obvious signal of the inability of the tank systems to provide a reliable water supply. In fact it has been observed that large numbers of tanks have become defunct in less tank intensive districts (i.e., 76% of Panchayat Union tanks and 64% of Public Works Department tanks have become defunct) compared to tank intensive regions, where the percentage of defunct tanks is less.

In Tamil Nadu, the share of tank-irrigated area to net irrigated area by marginal farmers has decreased from 39.53 percent in 1970-71 to 35.17 percent in 1990-91, area by small farmers has decreased from 32.02 to 0.23 percent, area by medium farmers (2-4 ha) has decreased from 30.03 percent to 21.47 percent and area by large farmers (more than 4 ha) has decreased from 28.46 percent to 19.40 percent. These numbers clearly indicate the poor performance of the tank irrigation systems in the state (Table 4).

The neglect of tanks has meant that most farmers must look to alternative sources for their water needs. To offset the decline in tank water supplies, farmers have resorted to supplemental well irrigation to avoid crop losses (Palanisami and Easter,1987, 1991). Since only about 15 % of the farmers in the tank command areas own wells, and since there is a growing demand for well water, the well owners tend to act like local monopolists and are able to charge high prices for well water. However, profit-making through privately owned water source (i.e. wells) within the hydrological boundary of the common property resource (tanks) poses serious threat to the very survival of the tanks since these new resources shift interest away from the wells. The level of well interference on tank performance is also different in PU and PWD tanks do to their disparate sizes.

The agricultural cooperative credit societies and banks providing loans further facilitated the intensification of the well investment. Hence, tanks were no longer an asset that needed to be maintained. At the same time, the prolonged deterioration has resulted in the acquisition of the tanks by opportunist villagers for their private cultivation. The village level irrigation institutions like *kudimaramath* also slowly became inactive and

powerless. Government funds have also been insufficient for the tank system's operation and maintenance (Palanisami and Easter, 2000).

The analysis of the well distribution in the tanks has shown that the well density (number of wells per ha. of command area) was relatively higher in PU tanks (0.42) than in PWD tanks (0.35), and these were not statistically different (Table 5). The reason for higher number of wells in PU tanks is that the duration of water supply is comparatively lesser in PU tanks (2-3 months) than in PWD tanks (3-5 months) (Palanisami et al.,1997).

Factors Affecting Tank Performance

Even though several factors influence tank performance, the level of their influences varies across locations. The major factors influencing the tank performance are given in Table 6. Well density has a negative influence of tank performance. Tanks without well supplementation had performed well which is clearly indicated by the availability of adequate tank water supplies.

Concerning the O & M expenditure on tanks at state-level, the results of the study indicated that although outlay per hectare of command area at current prices increased from Rs.26 to Rs. 161 per ha, the outlay at constant prices (1980-81) had increased only marginally from Rs. 33 to Rs.43 per ha. However, the O & M amount spent on sample tanks revealed that the average amount spent was higher for PU tanks (Rs 154/ha) compared to PWD tanks (Rs 74/ha). Since the O&M amount that was spent mainly depended upon the urgency of the tank repair and local political pressure, the level of tank performance and the amount of O&M spent could not be directly related.

Multi-uses from tanks

Traditionally, tanks were intended to be used not just for irrigation but also to help meet all local water needs such as for livestock and fish harvesting. However, due to changes in village profiles over the years, tanks are now almost exclusively used for irrigation needs. Therefore, when judging the tanks' feasibility and potential benefits, measuring the irrigation advantages may be inadequate as it will not reflect all the possible benefits that tanks can offer to the local community. Hence, multi-uses of the tank should be considered when analyzing tank performance. If such an analysis is done with this multi-use outlook, a radical rethinking of tank management may be warranted.

In absolute terms, social forestry raises the most revenue (averaging Rs 170/ha), followed by irrigation (Rs 88/ha) and fisheries (Rs 15/ha). Table 7, which presents revenue realized as a percentage of revenue mobilized from each use, however, paints a different picture. Social forestry collects the highest revenue as a proportion of total value of output (100%), while irrigation pays a relatively small proportion of the value of output (3.2 %) in various fees. Social forestry appears to perform well in absolute, as well as relative revenue realization at the tank level. Among the various agencies, Panchayat Unions receive the maximum realised revenue (64.96%), followed by the Social Forestry

Department (24.84%), village community (5.18%), and the Revenue Department (4.67%).

One may ask that if the panchayats generate so much income from the tank uses, why are they not investing more in attending to the maintenance of the tanks? The panchayats feel that it is the responsibility of the state government to pay for maintenance, and therefore do not put their own resources into this task. It is not clear what effect the Panchayati Raj Amendment has had on this particular situation, but it is essential to explore what will happen if the responsibility for tank maintenance as well as the entire revenue collection authority is given to a single institution such as local panchayats or water users associations.

Tank modernization

Given the poor state of the tanks, efforts have been initiated at various levels to improve those in the minor irrigation category. These minor irrigation schemes are intended to benefit tanks with an ayacut (command area) below 2,000 ha. In the State, 67 per cent of net irrigation area meets this criteria. The minor irrigation schemes are intended for the construction and maintenance of tanks, open wells and tube wells in addition to small irrigation works under streams. Apart from this, Special Minor Irrigation Programme (SMIP) is intended to facilitate the construction of new tanks, construction of anicuts, excavation of link channels, restoration of abandoned tanks, formation of percolation ponds, river pumping schemes, etc. The Desilting-cum-Reclamation (DCR) program was initiated to organize the desilting of tanks and to restore the capacity by reclamation of foreshore lands. Tank modernization programmes with European Economic Community (EEC) aid was also initiated during 1984-1992. The modernization works mainly included repairing tank bunds, sluices and surplus weirs and lining the field channels. But the catchment treatment part and partial desilting components have not been considered.

In general, the modernization programs were implemented as routine government programs without the participation of the beneficiary farmers. However, performance of the modernized tanks which included farmers participation was comparatively better than those tanks without farmers participation (CWR, 1998).

However, it is still not known what exactly is needed for the tanks in terms of tank modernization as each agency prefers their own highly biased agendas. For example, simple sluice management strategies might be more useful in managing the tank. Studies have shown that closing sluices for 2 days following a daily rainfall in excess of 60 mm dramatically improves performance (Palanisami and Flinn, 1988). The sluice rotation involves the opening and closing sluices on alternate weeks. The main purpose of this management strategy is to extend the period of tank water supply. It would increase the supply of lower cost tank water to later in the season and also would increase groundwater recharge. This example shows that research into tank performance and dynamics is extremely critical to policy making decisions.

Policies for improving tank hydrology

Investment

Tank rehabilitation options that restore original standards should be given priority Such as desilting. However, as stated earlier, in a 10 year cycle, only in 3 years, the tanks get full storage. In other words, the benefits of full desilting will be noticeable only during these three years. Also, disposal of all the desilted material is difficult since the useful fertile silt is found only in the top (0.4 meter) layer. For these reasons, full scale desilting may not be warranted. Considering the high cost of silt (Rs. 120/ m^3), partial desilting that helps to restore original dead storage (10%) could be attempted as part of tank rehabilitation options as this will help increase non-irrigation benefits of tank water particularly in the non-tank-irrigation season. Also, recharging of wells will be improved. Partial desilting can be done nearer to the lower sluice as well as around the periphery of the tank water spread area.

Most of the tanks are not getting adequate water supply and the chain system of tanks has been damaged. Hence, there is an urgent need to revive the tank-chains through appropriate modernization strategies for improving the supply channels connecting different tanks. This highlights the need for taking up modernization works at the chain-level i.e. by considering the entire hydrological boundary as a single unit rather than viewing individual tanks as separate entities for new investment. Community wells should be installed in the tank water spread area to provide a few supplementary irrigations to non-well farmers during critical periods.

Management

In general, the duration of water supply for PU tanks was comparatively lower (2.5 months) than for PWD tanks (3.0 months). In both PU and PWD tanks, the mean duration of conjunctive use of tank and well water was about two months.

The well density is higher in PU tanks compared to PWD tanks. Where water supply is scarce, the density of wells is very high and in such situations, such tanks could be easily converted as percolation tanks with the main aim of recharging wells and providing water to other village needs. This will help the tank farmer to harvest non-rice crops in the command area. Government and panchayats should make a list of such tanks and convince farmers to use them in a more productive way. The interest of the non-well owners should also be protected by providing the necessary supplemental irrigations for non-rice crops in the tank season.

Farmers in areas where water scarcity is acute have already adopted a crop diversification strategy involving groundnut, pulses, cotton and other crops and this practice should be extended to tanks whose water storage is 50-60 percent. The water required to produce one kilogram of rice ranges from 4500 - 5000 litres compared to 1500 - 2000 liters in the case of non-rice crops such as groundnut. Hence, even by using 50 percent of tank storage, the entire command area can be covered with non-rice crops. Extension efforts

and marketing support to farmers should be strengthened to introduce crop diversification, particularly in the wet season. Crop demonstrations by the Department of Agriculture should help speed up the process. To complement the above options, tank structures should be repaired for effective water control.

Canals account for 30 percent of water loss and also create inequity in distribution between head and tail farms. Lining main canals can be done without disturbing the field boundaries. Tank management strategies such as sluice rotation will help save the tank water by 20 per cent. Instead of continuous water withdrawal from tanks, sluices can be opened and closed on alternate weeks (rotation of sluices). The main purpose of this management strategy is to extend the period of tank water supply. Earlier studies (Palanisami and Flinn, 1988) indicated that closing and opening the alternate sluices in alternate weeks had saved the tank water by about 20 per cent besides extending the tank irrigation supplies to 2.5 months instead of the present supply of 1.5 months with continuous opening of the sluices. It would also increase ground water recharge.

Though most of the tanks have informal WUO, only about 30 percent of them in PWD tanks and 10 per cent of them in PU tanks are found to be active. The existing informal WUO should be given incentives by the Government in such a way that they will become formal and could generate more resources for tank management. This will also make headway for the revival of *Kudimaramath.*

It is important for local people be encouraged to use the tanks for cultivation of seasonal crops like water melon and various vegetables soon after the tank water is exhausted. This will facilitate the cleaning up of the water spread area by themselves. The water user's organizations should be empowered to implement this options without affecting the normal functioning of the tank systems during the rainy season.

Legal

More tank have become defunct in the recent years due to encroachment, siltation, choking of supply channels and pollution from industries. Tanks close to the cities should be protected from environmental pollution and further be made as groundwater recharges structures for domestic purposes. Strict regulations and penalty mechanisms should be imposed on the encroachers of catchment, supply channel, and foreshore area. Panchayats should be given powers to evict the encroachers as well as to prevent further encroachment even by the Government departments.

Fig 1. Share of Tank and Well Irrigated Area to Net Irrigated Area(NIA), India

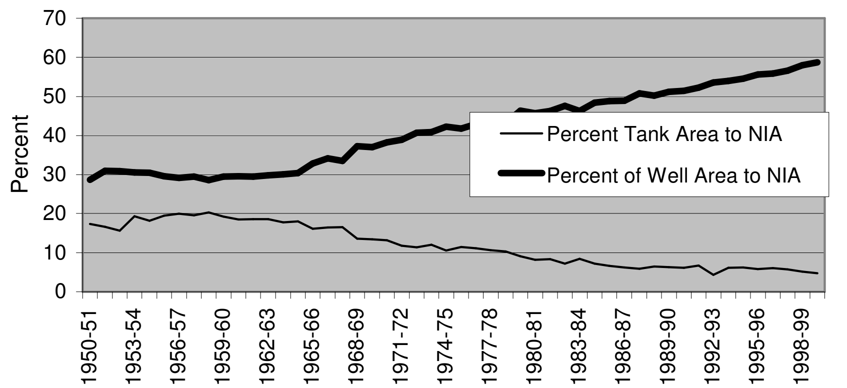


Table 1. Distribution of Tanks According to Types, Tamil Nadu

Tank Types	Command Area (ha)	Percent
I. Non-System Tanks (rainfed) Under:		
a. Panchayat Union (PU)	< 20	43
	20-40	10
b. Public Works Department (PWD)	> 40	13
II. System Tanks Under:		
a. Public Works Department (PWD)	> 40	9
III. Ex-Zamin Tanks	--	25

Note: The total number of tanks is 39200

Table 2. Tank Management Responsibilities in Three Indian States

State	Tank Command Area (ha)	Public Works Department	Revenue Department	Village panchayat
Andhra Pradesh	< 40	--	Revenue Collection	Maintenance, Repair, and Water Regulation
	40-400	Maintenance and Repair	Revenue Collection	--
	> 400	Maintenance, Repair, and Water Regulation	Revenue Collection	--
Karnataka	< 40	--	Revenue Collection	Maintenance, Repair, and Water Regulation
	40-80	Maintenance and Repair	Revenue Collection	--
	> 80	Maintenance, Repair, and Water Regulation	Revenue Collection	--
Tamil Nadu	< 40	--	Revenue Collection and Water Regulation	Maintenance and Repair
	> 40	Maintenance and Repair	Revenue Collection and Water Regulation	--

Source: Palanisami, 2000

Table 3. Rainfall and Tank Irrigation Probabilities

Average Wet-Season Rainfall (mm)	State of Tank Storage	Probability of Occurrence
> 500	Surplus or normal	0.10
450 - 500	Full or normal	0.20
300 - 450	Deficit	0.50
< 300	Failure	0.20

Note: Based on 46 years rainfall data.

Table 4. Share of different sources of irrigation in India and Tamil Nadu (%)

	Source	1960-61	1970-71	1980-81	1990-91	1999-2000
India	Canals	42.05	41.28	39.40	35.63	31.29
	Tanks	18.50	13.22	8.24	6.84	5.18
	Wells	29.56	38.22	45.70	51.04	57.81
	Others	9.89	7.28	6.66	6.49	5.73
	All	100	100	100	100	100
Tamil Nadu	Canals	35.80	33.90	32.70	32.40	27.58
	Tanks	38.00	34.50	32.10	22.38	19.47
	Wells	24.20	29.80	33.80	44.61	52.88
	Others	2.00	1.80	1.40	0.61	0.37
	All	100	100	100	100	100

Source: Tamil Nadu - An Economic Appraisal (Various issues)

Table 5. Frequency distribution of sample tanks based on well density

Tank Type	Well Density (No. of wells / ha of command area)				
	0	0.01-0.10	0.11-0.50	>0.50	Mean Well Density
PU	96 (24.81)	39 (10.08)	150 (38.76)	102 (26.36)	0.42
PWD	8 (4.55)	39 (22.16)	86 (48.86)	43 (24.43)	0.35

Note: Figures in parentheses are percentage to total number of tanks.

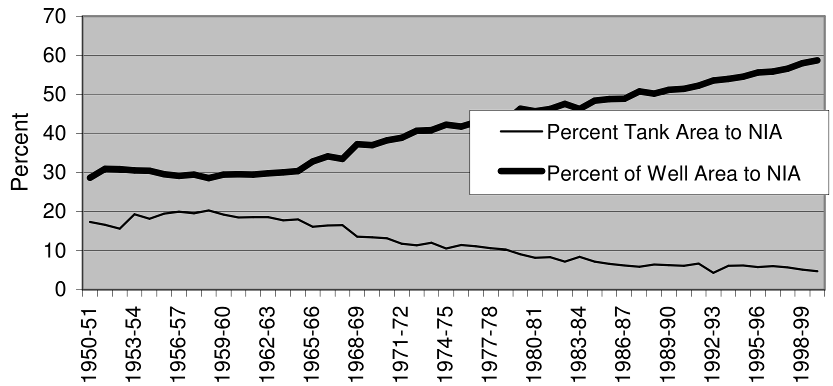
Table 6. Parameters Influencing Tank Performance Under Different Levels of Adjusted Tank Performance

Tank Type	Adjusted Tank Performance (%)	Well Density (No./ha)	O&M Expenditure (Rs/ha/year)	Resource Mobilized (Rs/ha/year)	Encroachment (% of water spread area)	Farmers' Participation (man days /ha/year)
PU	<25	1.30	73.80	28.00	34.44	0.28
	25-50	1.00	12.07	0.60	20.26	0.20
	50-100	0.30	154.00	8.25	12.24	0.56
	>100	0.00	24.00	0.00	8.22	0.72
Mean	75.70	0.42	154.00	9.00	16.23	0.54
PWD	<25	1.25	28.50	68.80	19.76	0.09
	25-50	1.00	108.00	61.30	11.66	0.35
	50-100	0.30	73.20	9.45	6.99	0.49
	>100	0.00	--	--	--	--
Mean	83.30	0.35	74.00	14.00	10.23	0.30

Table 7. Average Revenue Realization at Tank Level from Multiple Tank Uses (Rs/ha)

Tank Type	Irrigation	Fishing	Ducks	Bricks	Social Forestry	Trees	Silt	Total
PU, Head	80.38	6.67	0.24	0.47	228.09	2.55	0.00	318.40
PU, Tail	51.66	17.00	0.41	0.08	284.01	2.70	0.00	355.85
PU	66.02	11.83	0.32	0.28	256.05	2.62	0.00	337.12
PWD, Head	101.04	3.36	0.07	0.21	242.22	0.41	0.00	347.31
PWD,Tail	88.21	20.83	1.42	0.10	49.27	1.07	0.00	160.88
PWD	94.05	14.62	0.60	0.14	160.10	0.77	0.00	270.29
Average	88.00	14.87	0.48	0.15	170.85	1.05	0.00	275.40

Fig 1. Share of Tank and Well Irrigated Area to Net Irrigated Area(NIA), India



Ch11

Traditional Hydraulic Technology of Uttaranchal

Manikant Shah & Pankaj Goyal

There is quite a bit of literature on temple architecture and iconography of the Central Himalayas, but very little on secular architecture and water related structures. We are aware of the valuable efforts of the Indian Science Academy, the Infinity Foundation and the Centre for Civilisational Studies, Delhi towards the reconstruction of India's History of Science and Technology. It is, however, sad to note that even historians of technology have somehow ignored this particular valuable scientific heritage of the Central Himalayas. The need to study this traditional hydraulic technology, therefore, should be urgently addressed.

Our preliminary explorations clearly show that such hydraulic structures are examples of the great ingenuity of the ancient people of the region and are intricate models of architecture. In the course of the millennia, the hilly people learnt and devised techniques to locate sources of perennial springs with the help of some diagnostic plants; they made use of particular types of clay to purify and retain water; they also used various techniques like copper plates to purify water.

In this study, we propose to survey, document and analyze such ancient hydraulic structures and their technology. We have found that both domestic and hydraulic architecture attained great heights, yet has not yet received the attention it deserves., However, we hope that the proposed study will have considerable relevance not only to the history of traditional technology but also to environmental conservation.

To provide a backdrop, we have provided here an outline of the story of such ancient water harvesting devices in an all India perspective and then a glimpse of such remains in the Kumaun region.

A Brief All India Survey

Water harvesting means collection, storage and utilization of all locally available water that includes precipitation, surface run-off, snowmelt and groundwater springs etc. Water has been harvested in India since antiquity. We can see the evidence of this tradition in ancient texts, inscriptions, folklore and also in archaeological remains. There is some evidence of advanced water harvesting systems even since prehistoric times. The *Puranas, Mahabharata, Ramayana* and various Vedic, Buddhist and Jain texts contain several references to canals, tanks, embankments and wells. Numerous treatises on agriculture and architecture also provide details about them.

With the advent of first human regular settlements about 6000 years ago, the use of hydrological techniques has been an imperative. Storage of water in cisterns was known by the time the first cities were built. The ancient cisterns were hewn into rocks. Masonry cisterns developed at a later date. The first great civilisations, in the valleys of the Indus, Nile, Tigris, Euphrates etc flourished only on the basis of water management.

The vast Indus Valley Civilization (c. 2600 to 1900 BC), which became known with the excavations of Harappa and Mohenjodaro in the early 1920s, developed standards of hydraulic structures that were not equaled even by the Romans, whose water supply systems are generally considered excellent. Wells were probably a Harappan invention. A recent archaeological survey of the Indus Valley Civilization revealed that every third house had a well.

The earliest evidence of irrigation in the Indian subcontinent goes back to the beginning of the third millennium BC in Baluchistan. The structures found there are known as *gabarbands.* They are basically built as a series of platforms which are about 60-120 cm high. They rise in successively receding steps, gradually narrowing towards the top. Dams of this type are common in the Hab valley.

Literary References to Water management

Early Hindu texts, written around 800-600 BC, reveal some hydrological knowledge. The Vedic hymns, particularly those in the *Rgveda*, contain many references to irrigated agriculture, river courses, dykes, water reservoirs and water lifting structures. The *Chandogya,* one of' the principal *Upanishads,* points out:

> *"The rivers...all discharge their waters into the sea. They lead from sea to sea; the clouds raise them, to the sky as vapour and release them in the form of rain..."*

This is probably the oldest reference to natural processes of the hydrological cycle. It shows that as early as about 1000BC attempts were being made to interpret and explain recurrent natural phenomena on the basis of direct experience.

The *Arthasastra* is a treatise on government and economics in ancient India and is ascribed to Kautilya, the chief adviser to India's first emperor Chandragupta Maurya. There is enough evidence in the book to indicate that the people knew about rainfall regimes, soil types and appropriate irrigation techniques in specific micro-ecological contexts. Another important source is Kalhana's *Rajatarangini,* the chronicle of the kings of Kashmir, composed between 1148 AD and 1150 AD. It is replete with information on canals, irrigation channels, embankments, aqueducts, circular dykes, barrages, wells and water wheels.

It is clear that India has a very old tradition of water harvesting. These traditions have developed over centuries in an eco-friendly manner. The variety of water harvesting structures arose from the ecological and geological diversities of the country. Some of them were originally constructed by local rulers, feudal lords and by some wealthy

families in the community. Over centuries, our ancestors developed a range of techniques to harvest every possible form of water from rainwater to ground water, stream water to river water to floodwater. India has a variety of ecological regions – from the dry, cold, desert of Ladakh to the dry hot desert of Rajasthan. From the sub temperate high mountains of the Himalayas to the tropical high mountains of the Nilgiri or from the plateau of Deccan to the backwaters of Kerala etc. Every particular region has developed its own indigenous system of water harvesting. For example, *Kundis* of Rajasthan are covered underground tanks with an artificially prepared catchments area to collect rainwater. In Meghalaya they have a 200 years old system of tapping stream water or spring water by using bamboo pipes. Some other indigenous examples are *Arakare, Katte* and *Kola* in Karnataka, *ahar-pyne* systems of Bihar, *Zabo* system of Nagaland, *Baoris* of Himachal Pradesh etc.

Hydraulic Structures in Uttaranchal

The Central Himalayan region includes tremendous geological and ecological diversities and these conditions have led to a glorious profusion of water harvesting systems. According to folklore, our ancestors created various water systems for different purposes. For human consumption, people used to prefer the water of *naulas* or tap springs *dharas* or *mungurus* rather than drinking water from other sources. For animal use, irrigation and washing, they developed open water bodies like, *chaals, khals, guhls, kuhls, dhands, jalkunds, khais, bhumkas, chuptyalus* etc. A brief description of these structures follows.

1. Chaals/Khals, Chuptyaulas & Simers:

A variety of natural formations and depressions in the mountain areas are used for rainwater harvesting among which are *chaals* and *khals*. *Chaals* are usually found along mountain ridge tops in the saddle between two adjacent crests. *Khals* are somewhat larger than *Chaals*. These were mainly used for animal consumption.

Two other natural rainwater harvesting systems are *simers* and *chuptyaulas. Chuptyaulas* are rudimentary structures found in high altitude areas of Uttaranchal which collect water from springs. *Simers*, on the other hand, are natural formations in the form of water-logged flat lands. Some specific crops like basmati rice or medicinal plants and herbs are grown in these *simers*. Kumaun has several *simers* in its vast area.

2. Guhls and Kuhls:

Archaeological excavations reveal that terraced agriculture has been practiced in the Central Himalayas for thousands of years. In Uttaranchal, the irrigating systems in terraces have historically been made by diverting water from nearby mountain streams through channels known as *guhls*. They are small, gravity flow irrigation channels that gently terrace the contours of a mountain slope. Though *guhls* are primarily meant for irrigation, some also provide hydropower for *gharats* (water mills). At present, *guhls* are also known as *nahar* (canal). A *Kuhl* is also somewhat like *guhl*, though a little smaller than it.

3. Dharas/Mungurus:

A common source for drinking water in Uttaranchal is from *dharas,* also known as *mungurus*. It is essentially a drinking water fountain; water from springs or subterranean sources is channeled out through craved outlets. These outlets are often in the shape of either a simple pipe, figure of women with water pitchers or in the form of animal facemask. However, the animal facemask types found most frequently. The shape of an outlet is made in such a way that even with low water pressure, water can be easily drunk. The degree of detail, ornamentation and decoration of *dharas* varies according to the status of the builder. These *dharas* often bear inscriptions paying tribute to various rulers of the region.

4. Bhumka and Gadheras:

In the rainy season, sometimes when water seeps outside through land then it is known as *bhumak* or *bhumka*. The bhumka gets its name from the 'bhak-bhak' noise that is emitted when water flows through it. Because of this noise one can easily detect the presence of water. *Gadhera* is the depression between two hills. In these *gadheras*, water is conserved which is then used for livestock use and for washing and bathing purposes.

5. Jalkund and Taal:

Where there is scarcity of water, the villages tend to make small tanks near *dharas*, *naulas* or *simers* for the livestock. These are known as *jalkunds* and are found commonly in Kumaun.

Natural depression in land filled with water like in a pond is locally known as a *taal* while big depressions are called *jheels*. Sometime, due to landslides, land that is surrounded from three sides takes the shape of a *taal* on the forth corner. Landslides in any flowing *nala* also creates *taals.* A turn in a flooded river can also develop into a *taal*. There are 12 *taals* in the Nainital district alone and are of various shapes and sizes like *Bhimtal*, *Adamtal* and *Khurpatal* etc. *Gorital* in Pithoragarh and *Shyamtal* in Champawat are also the examples of this category. Primitive men took water from the rivers, valleys or *taals* as the types of taals*/ tadags/ taalabs* are described in the *Aprajitaprichha* (74-32-34, *Vaasturaj*, chapter 29).

6. Kot ka Kuan (Fort Well):

Round or square shaped tanks made in high mounds were constructed in several locations and are known as *Kot ka Kuan* (fort well). The water from these wells were used only in emergencies. Some of examples are the well of Banasur fort, Uncha Kot, Gorkha Kila, Karki kot and Sira Kot. Interestingly, these tanks have a symbolic value in that they represent the patron king's victory.

These Fort wells were a type of direct rain water harvesting system. Today's water harvest tank technology is inspired by the *Kot ka kuan* technique.

7. Dhaadh:

When our ancestors started living near hilly slopes rather than river valleys, they modified the water of flowing *nalas* in the form of small ponds, which are called *Dhaadhs*. These *Dhaadhs* were meant for livestock use and were also a place for bathing and washing. A water canal or *ghul* can also be drawn from it to irrigate agricultural fields.

8. Naulas:

Naulas are the most impressive marvels of Central Himalayan traditional water technology. *Naula* is a method of groundwater harvesting typical of the Uttaranchal region. Water is collected by making a stone wall across a groundwater stream.

Since antiquity, the hill folk of Uttaranchal have been drawing water from *naulas* for different purposes. They are chiefly found in the middle Himalayan region of Kumaun. They are designed to collect water from subterranean seepages or springs and were used to meet domestic water needs by the local communities.

Naulas were traditionally held in deep reverence by villagers and the rituals observed while constructing a *naula* were similar to that of a temple. For the treatment and purification of *naula* water, leaves of medicinal plants and fruits like *anwala* were added periodically. Big shady trees were planted near *naulas* to reduce evaporation. Besides these practices, there was also a custom to worship *naulas*. These *naulas* had dual effects: not only did it teach the villagers to keep the *naula* clean, but also to conserve water.

Current State of the Naulas and other hydraulic systems

Today thousands of *naulas* throughout Uttaranchal lie forgotten and are decaying. It is believed that at one time Almora alone had 360 *naulas*. However there is no recorded data to authenticate this fact. A recent study has identified 99 *naulas* out of which only less than 40 are functioning today.. Their degraded condition reflects a serious decline in community water management. Most significantly, the traditional technology of locating water sources, building and designing these structures is gradually being forgotten. Yet, faced by the threat of declining water sources, some communities have made efforts to renovate and revive some *naulas* However, this first requires the understanding of the ancient technology without which renovation is not possible.

Unfortunately, many obstacles exist, and continue to grow. With the nationalization of the water resources, communities have tended to become alienated from natural resources. Urbanization continues to force itself into the remotest areas. Other hydraulic structures are also in as state of utter neglect. Such neglect has its effects on the massive

runoffs, water scarcity, water related disasters, drainage problems and violent climatic changes. It is obvious that serious thought and reform must take place on our water management strategy to combat these problems.

Relevance to Sustainable Development

The problem of water supply has been made more complex and inequitable both by humans and nature. Nature has endowed the planet earth with plenty of water but 97.5% of it is not potable as it is salty. Of the remaining 2.5% of fresh water, distribution falls between lakes & rivers (0.3%), ground water (30.8%) and in glaciers (68.9 %). As surface water is being consumed fast, there is enormous pressure on the exploitation of ground water. To make matters worse, with the advance of global warming, the glaciers are receding at the rate of 15 meters per year. The West has further stressed our limited resources by its inequitable consumption of water: Whereas a poor Gambian in Africa uses only 4.5 litres, an average American uses 587 litres of water per day! As water is in short supply, some people are forced to consume polluted water As a result more than 5 million people die of waterborne diseases, which is ten times more than the number killed in wars!

Even in Uttaranchal, which is blessed with two monsoons in the winter and summer, water scarcity still is a serious problem. Though on the average the area receives 1000 cm of rainfall per year, most of it runs off, taking with it precious surface soil also. The increase in population has resulted in the growth of towns with increased demand of domestic water supply from the tap.

Today, out of the 360 odd *naulas* and *dharas* in the town of Almora in Uttaranchal, less than 40 are functioning. Obviously, this source of pure mineral water has been allowed to go into disrepair. As a result, Almora is forced to bring water from the Kosi River located 10 kilometers away. Even then the supply is still not adequate. The local farmers upstream have been denied use of water for their farms. Several desperate measures have been taken (setting up hand pumps, increasing pumping of river water etc) in spite of the existence of the traditional naulas and dharas. Efforts to provide entire habitations, rural or urban, with drinking water from water pump and lift schemes are beginning to seem impracticable and spell of further environmental disasters. The solution lies somewhere in the revival of the traditional water springs and *dharas* and augmenting the water supply through water harvesting. The present book will try to present the traditional hydraulic technology of Uttaranchal in its entirety so to not only document it, but also to useful information in tackling the impending water crisis.

Global warming is going to increase in the coming decades and a lot of precious glacier water will eventually reach the sea through the rivers. They say the question of water is going to trigger off the third world war. The proposed Book Project is a step in the direction towards the study of a more complete look at not just technology but also the relationship between man and technology. This book examines the traditional hydraulic systems of a people who, rather than viewing the forces of nature as inimical to

humankind and fit to be subdued, saw instead the benevolence of nature and acted in harmony with her.

Ch 12

Indian Indigo and Its Spread Around the World

Padmini Tolat Balaram and S. Balaram

"Complex and difficult as the art of dyeing with indigo is, it is more intimately associated with the early human race than any other dye or pigment." (Watt 1890 IV: 390)

"A fragment of coarse madder-dyed fabric in a plain weave, found during the excavation of the ancient Harappan sites indicate that even the people of Mohenjodaro (c. 3000 B.C) used natural dyes (Mohanty et al. 1980:1, Marshall:33)

Indigo is the oldest natural dye used by human beings. It was a very important dye until the beginning of 20th Century.

Indigo yields a wide range of blue colours, from the darkest to the lightest. Initially, however, its use was limited to dye cloth backgrounds black. India was the first country which had mastered the technique of extracting indigo and successfully using it to dye the whole spectrum of blues, starting from light blue all the way to deep blue, which was very close to blue black. Indigo was also used for dyeing green and purples in combination with other natural dyes.

Etymology of Indigo

Indigofera

It is believed that the word Indigo was derived from word India. Indian author Rumphius appears to have regarded Indigofera tinctoria as indigenous to Gujarat. (Watt 1890 IV: 389) Indigofera tinctoria was a cultivated variety of indigo specially used for producing high quality dye.

Very few people know that Indigo dye is extracted from various plants belonging to Genus Indigofera, and is not the product from just one plant species.

In India, total 40 species of Indigofera genus grow. Out of these 40 species, 8 yield indigo dye. Out of these 8, 4 were cultivated for the purpose of export during British Era. Indigofera tinctoria became most famous as an item of export during the British rule in India. (Watt 1890 IV: 389)

According to G. Watt, Indigofera coerulea was a plant originally found growing wild in India and Africa. From this Indigofera coerulea plant, the modern indigo dye-yielding plant stock, called Indigofera tinctoria, was derived through cultivation. Before Indigofera tinctoria was cultivated in India, however, other Indigofera species also indigenous to India were used to achieve a blue colour. Indigofera coerulea, in fact, was one such species along with others like I. hirsuta, etc. (Tolat 1980)

Sanskrit speaking people must have been first to make the acquaintance of Indigofera tinctoria, as the name 'Nila' was used in all the languages of India and later also spread to Europe. We can assume that 'Nila' was referring to indigo since it was apparent that India was exporting indigo plants while the rest of the world did not have any knowledge of indigo dye extraction. Here it is important to state that the other species of Indigoferas, which are also indigenous to India, had their own separate vernacular names in all Indian languages (Watt1890 IV).

In some languages and dialects, there were comparative and descriptive names for indigo. These descriptive names indicated the specific qualities associated with the plant dye by different groups of people and their methods of preparing the dye. It also indicated a previous knowledge in other blue dyes. Some of these names are:

Kannada- 1. Ollenilli (Olle means good, meaning good indigo)
2. Hennunilli (female indigo)

Tamil - 1.Aviri (Avi means boiled, thus this name indicates that the dyeing Technique included boiling process
2.Karundoshi (black indigo). There is a great relation between these two names. When indigo was used for dyeing black colour, the dyeing was carried out by boiling the dye.

Sanskrit -1. Nila (blue) and many other descriptive names like
2. Vajranili (hard blue)

Gujarati - 1.Gali (decoction) This name very clearly indicates that the dye was fermented to reduce the indigo, to make it soluble in water. This is the traditional technology which was invented in India and in which India had excelled centuries before any other civilization came to know about it. (Watt 1890:IV)

Other Blue Dye Yielding Plants

Apart from Indigofera species, plants belonging to other genus were also used to extract blue dyes. However, by the time this technique of extracting blue dye from other plants became popular, indigo of India was quite well known and had become very poular and widely used. Hence all blue dyes, no matter if they were extracted from Indigofera or any other genus, were called indigo. For example, Japanese indigo, which was introduced in Japan during Nara period, was extracted from Polygonum tictorium, and yet came to be known as Japanese indigo. (Balaram 1996 525)

In India, Tephrosia purpurea was used in Gujarat to make indigo dye.. Assam Indigo was and is still extracted from Strobilathes cusia (now known as Bapicacanthus cusia) and Strobilanthes flaccidifolius.(Balaram and Balaram1998-99) This plant seems to be native of Assam but has traveled to Myanmar, Thailand, Laos PDR., and Southwest China, from

where it reached the Okinawa islands of Japan. To this day, the dyes extracted from this plant continue to be used.

Apart from plants, leaves of a tree known as Wrightia tinctoria were also used for extracting blue dye in south India. In Madras, Nerium indigo was made using these leaves. (Watt 1890 IV: 451)
Wild indigo (Baptisia tinctoria), was also used for extracting dye
In upper Asia and Europe, Isatis tinctoria, commonly known as woad, was the main source of blue dye.

Sanskrit word "Nila"

"The word nila simply denotes the dark blue colour, and is, with many of the early writers, practically synonemous with kala (black)" (Watt 1890 IV:390)

In India, two different techniques existed for dyeing blue and black using indigo. Due to this, the word 'nila' not only meant blue, but was also associated with black as well. This plant was used to prepare black colour all over the world before its property to dye blue was discovered.

The word nila also means dark or blue and is used as an adjective in the case of human being, animals, plants and minerals. The name 'nila', 'nil' or 'nel' is associated with large number of plants like water-lily (Nymphea lotus) which is also known as Nilufar and Nuphar and sacred lotus is called Nelumbium. (Watt 1890:IV)

> *Word nil is also used for describing animals and birds such as nilgai meaning the blue cow (Portax pictus), the blue stones called as nilopala (lapis lazuli) and nilaratna (the sapphire). (Watt 1890 IV: 391)*

Nilabha (clouds) and Nilambar are other such words, which represent indigo colored clouds and sky respectively. The color of Krishna, the Hindu deity, is associated with the indigo color of the sky and is known as having 'Nilambara varna'. His name 'Krishna' itself means black, a color derived from indigo as mentioned earlier.

Thus, Nila substantively is a plant which yields a blue or dark colored dye. So it seems that the meaning of the word 'nila' ranges from general to specific and probably obtained its restricted meaning from Indigofera in India, and that too perhaps only during comparatively modern times. (Watt 1890 IV)

John Huyghen van Linschoten, whose journal of Indian travels was published in 1596, very carefully describes the manufacture of what he speaks of "Annil or indigo, known as Gujaratis as Gali, by others as Nil". (Watt 1890 IV: 391).

Techniques of Indigo Manufacture and Dyeing from Indigogera

Indian indigo was known to be a very fast dye and a superior blue dye compared to the others blue dyes used in the world. Elijah Bemiss, a known dyer from Europe, observed

in 1815 ”We are not furnished but a true drug that give a permanent blue, and they are, indigo and woad.” The reason for distinguishing the two is that the traditional processing of woad leaves produced a low indigo yield suitable for dyeing absorbent wool fibers, whereas the foreign indigo plants yielded much higher concentrations which were ideal for dyeing less absorbent fibers such as cotton and flex. (Balfour 1998: 2)

What made Indian indigo far superior than the other blue dyes of the world was its quality and quantity of dye content. In India, mainly 3 techniques were used for manufacturing indigo. (Tolat 1980) The most famous method, which yielded the best dye, was extraction of dye using a wet fermentation method carried out using fresh leaves. Next was wet fermentation method carried out using dry leaves to facilitate dye extraction far from the indigo field during off-season. Another method, which was practiced by a Himalayan tribe, was by fermentation of leaves, a method similar to the one which is presently followed by Japanese dye-makers in the production of their sukumo dye.

In most of the places in the world, indigo dye was prepared by fermenting the leaves of a blue dye yielding plant. India was the only place where extracting the dye from the leaves was known at a very early stage. The Indian method of extraction differed in the fact that the leaves submerged into water to extract a dye. Indigo, when extracted from leaves by this method, is more pure and has more dye content in it. It also becomes compact, which helps in transporting and it stays unaffected by weather for years together. The author conducted testing in 1995 which compared dyeing with Japanese indigo and with Indian indigo cakes. It was shown that Indian indigo was 20 times stronger than the Japanese sukumo which was made by fermenting the leaves of Japanese indigo plant, Polygonum tinctorium.

For this reason, Indian method of extracting indigo using process of wet extraction later spread to all over the world. Today the same method is now used with many other blue dyeing plants such as Strobilanthes flaccdifolius in Okinawa, Japan, in South west China. North Thailand, Laos etc.

Indigo dyeing techniques and ingredients used with it also play an important part in the fastness and strength of the color that is dyed. India had developed methods of dyeing wool, silk, cotton and other bast fibers, which are fibers that come from stalks of plants like jute, ramie, and linen, since a long time. In Gujarat special sweet vats were prepared to dye silk and wool, which usually get damaged in the highly alkaline vats required to dye cotton and other bast fibers.

Indian indigo dyeing technique allowed brilliant light blues as well as deep dark blues. Indigo dyeing techniques used in South-east Asia, gives reddish tint to the dark blues, but dyes very grayish light blues (Balaram 1980).

Conte in 15th century and Taverneir in 17th also minutely describes the manufacture of indigo. (Watt 1890 IV: 391)

Use of Indigo along with various decorative techniques in Indian Textiles

Indigo was used for dyeing yarn blue and black which were, in turn, used to weave designs. It was also used for dyeing yarn for embroidering. However, indigo was used most extensively with resist dyeing techniques. As indigo is excellent as a cold dye, wax resist and mud resist techniques had developed which were used along with printing. Other resist techniques were of mechanical resists such as fabric and yarn tie-dye. These resulted in production of tie-dyed bandanas, Laherias and Motharas. Yarn resist techniques were used to produce a group of ikat fabrics such as Patan Patola, Telia Rumals of Andhra, and Ikats of Andhra and Orissa.

Early references to resist techniques lead us to conclude that use of indigo was highly prevalent during those times, as mainly indigo was used with resist techniques.

> *The best early documentation of the sophistication and variety of textiles worn several thousand years ago comes from the paintings in the Ajanta caves. Second C. BCE-fifth Century CE). They verify that the weaving of fine muslins with decorative schemes such as brocades, embroidery and tie-dye were already in use in Indian society. (Johnson 2003: 296)*

"Because Indian textile makers had developed resist-dyed colour fast textiles, Indian fabrics were eagerly sought by people in Africa, Asia and Europe until the late nineteenth Century." (Johnson 2003: 296)

Apart from dyeing, indigo was also used in painting Buddhist Tangkhas, miniatures paintings, Pichwais of Nathdwar, and Kalamkaris of South India

Indian Indigo, Its Spread and Trade Around the World

"Indigo has always been an essentially eastern product and ancient Sanskrit writings describe the method of preparing it. Thus it appears that use of this dye can be traced as far back as 4000 years. In fact Egyptian textiles of 1600 B.C. still bear remnant of this dye."(Watt 1890 IV)

In 1993, the British Museum found a record of indigo dyeing process inscribed on two pieces of clay fragments belonging to the Neo-Babylonian cuneiform tablet, dated to the 7th century BCE. The indigo dyeing process inscribed clearly mentioned the characteristic repeated dippings and airing necessary to produce lapis coloured wool (uqnatu), but does not mention the dye source. (Indian indigo may have reached Mesopotamia by this time)*25 Other recipes described over-dyeing to produce reddish and bluish purples. (Balfour 1998: 17)

Finds from the important Indus valley site of Mohenjo Daro indicate that by the second millennium BCE, Indian textile technologies were highly developed. It is probably that indigo dyeing skills had developed by then too, but early samples of Indian dyed textiles are rare and none exist that confirm the use of indigovidence for its use in India before the medieval period is, therefore, based on written sources. This includes 'Periplus of the Erythraean Sea,' written by an anonymous trader in Egypt in first century CE. Since India was the linchpin of early trade both eastwards and westwards and was highly accomplished in textile arts, much technical know-how must have filtered along the trading routes. Consequently, her trade in textiles must have had an enormous impact globally. (Balfour 1998: 18). For example, in Egypt:

> *An indigo or a blue dye was used in remote times there can be no doubt as since it has been detected in the colour borders of some of the Egyptian mummy garments. (Watt 1890 IV: 391)*

The spread of indigo exported from Barbaricon on Indus River (It does not exist now but must be somewhere near present Karanchi in Pakistan) was recorded in all parts of the world. Dioscorides (A.D. 60) speaks of indigo as 'Ivcikov", Pliny calls it indicum, and in Periplus it is 'Ivoikov peyav' or the Indian black. The word black is instructive both from its association with Nila and from the circumstance that the dye was used as a black colour before its property of affording blue was discovered.

The references to nili (indigo) and manjistha come from Warangal from the period of Kakriya Ganapatideva, in connection with joint donation by foreign and native merchants from a levy on their trades. *64 (Ramaswamy 1985:18)

According to Mira Roy, Pp 84-85, "the tinctorial properties of vegetable substances, recognized in Vedic period, particularly in Athavavedic and succeeding period (c. 1000- c. 500 B.C.), were kala or asikni (possibly indicating indigo,maharanjana, manjistha, lodhra and haridra)."(Mohanty, Chandramauli, Naik, 1980:1)

Indigo and indigo dyed textiles were also traded on the Silk Road, starting from 2nd Century B.C. Silk road started in China and went through several Asian and a few European countries on its way to reach its last destination Constantinople. There were many sub routes. One of such sub route which went via Kashmir, joined India to the main silk road. Indigo resist-dyed cotton and the more usual woolen dyed yarns for pile textiles have also been found among the thousands of specimens dated to the late 2 nd century BCE to 5th century CE. These samples were excavated in the at-tar burial caves of southwestern Iraq, a silk route trading centre. (Balfour,1998:17)

The dyestuffs introduced in the post-Vedic period (c. 500 B.C. –c. 3rd century A.D.) included nila (indigo) among the plant products.

As for Southeast Asia, Indian indigo plant, Indigofera tinctoria, seems to have been introduced to drier parts of Indonesian Archipelago around the first millennium B.C. along with the Sanskrit name nila. (Balfour 1998: 19)

"The word indigo itself derives from the Greek indikon, Latinised indicum, originally meaning a substance from India, indicating the import of indigo by Greco-Roman world. The Sanskrit word nila, meaning dark blue, spread from India east words into South-east Asia and westwords to Near and Middle East, probably both through pre-islamic trading routes and with the subsequent trade and with the subsequent trade diffusion of product in the Islamic era." (Watt 1890 IV: 390-91, Balfour 1998: 11,)

Sangam texts are also replete with references to Indian dyes. Cloth dyed with indigo is referred to a nilikachhai in Puananaru. (Ramaswamy 1985: 4). Huge brick dyeing vats pertaining to the first and second centuries have been unearthed from Arikamedu in Pondichery and Uraiyur in Tiruchirapalli, both known to be important weaving centers in the book "Periplus of the Erythraean Sea". (Ramaswamy 1985: 4)

Hamida Khatoon Naqvi (pp. 58-70) provides an account of some of the processes involved in dyeing and printing cotton fabrics in Mughal India (A.D. 1550-1800) She makes an interesting observation about use of indigo, "The same desire to reduce the cost reflected in their occasional use of chaukunda (Cassia tora), yielding a blue dye, which could be fixed by adding lime and water." (Mohanty *et al.* 1980:1)

I have my own doubt about this statement that using Cassia tora seeds as an alternative to blue of indigo is possible. In south India, these seeds are employed as a reducing agent with indigo to set up fermentation in indigo vat for dyeing, while using indigo cake for dyeing. There could be some mix up in thinking them to be the blue dye by themselves. During my experiments, these seeds on their own yielded a weak yellow colour. The addition of lime did not turn the solution to blue either.

The quality of Indian dyeing too was proverbial in the ancient world. In St. Jerome's 4th Century Latin translation of the Bible, Jerome says that wisdom is more enduring than the dyed colours of India (Ramaswamy 1985:3)

Along with Buddhism, Indian indigo also traveled to China, Myanmar, Thailand, Japan and other parts of South East Asian Countries:

> *In the Far East cultivation of indigo spread slowly eastwards from the Indus Valley. It is thought that the indigo plant and way to use it probably came to Japan from China by way of Korean artisans together with Buddhism, in about 5th century A.D. (Balfour 1998: 26,Tomita Jun and Noriko:1982, Japanese Ikat Weaving, London 7, 70-77)*

The Manasollasa says that in tie-dye weaving (Ikat), pleasing colours were used. Reference is made to manjistha, laksha (lac) used as a mordant, kusuma, haridra and nili.

It also refers to abhayarasa as yielding black dye and nisha (deep blue or black). Cloths dyed the colour of peacock blue is also mentioned. (Ramaswamy,1985:19)

The Arabs conveyed the word nil, or with definite article, an-nil, further west in the course of their conquests across North Africa and into Southern Spain. Subsequently Spanish and Portuguese transmitted the word anil and anilera to Central and South America in 16th Century (Balfour1998: 11). Later, the word Anil was associated with one of the speices of Indigofera, which came to be known as Indigofera anil, and was cultivated for producing indigo in America. (Watt, 1890 IV: 383) “Dry leaf indigo of Madras, is to some extend obtained from this species.” (Watt 1890 IV: 383)

Speaking of Akbar’s conquest, Percival Spear has mentioned, “Fertile Gujarat with its cotton and indigo was first secured in 1572, bringing with it the port of Surat with its trade to Arabia, the Persian Gulf and Egypt.”(Spear 1990) (“A History of India”, volume two, pg. 31)

While talking about the trade during Mughal Empire Spears remarks:

> *The movement of trade was severely limited by transport difficulties; bulk articles could only be transported down the rivers or overseas. Such were sugar from Bengal and saltpeter from Bengal. Intermediate articles such as indigo, opium, tobacco and cotton goods could be transported at a price which meant that they went by water or became luxury goods through expense. (Spear 1990)*
>
> *“India had an active trade with the Middle East and Europe, the main articles of export being textiles, indigo, saltpetre and spices. “(Spear 1990: 45)*

During Aurangzeb’s rule:

> *The pattern of thread which developed was one of steady rather than spectacular returns. And it presupposed reasonable tranquility in the country. In the west the main articles were cotton piece-goods, cotton yarn, and indigo from Gujarat. (Spear 1990: 67)*

In the 17th century Indian indigo was most commonly used dye in the world. The price of cloth and earning of weaver depended on the price of indigo. The best indigo came from Surat, but the Coromondal coast in Naglewanch was supposed to have produced quality product also. Some indigo was produced at Dabhol, and Wensurla in Bijapur as referred to as dyer’s village in the Dutch records (Ramaswamy, 1985: 122)

In 1614, Masulipatnam indigo cost 12 pence per pound, while Surat indigo cost 13.5 pence. 25 Sarkhej indigo (near modern day Ahmedabad) usually ranged between Rs. 15 to 20. Biyana indigo was much more costly. (Ramaswamy, 1985: 123)

Introduction and trade of Indigo in Europe and Western Countries

Records show that 12th century Venetians were the first Europeans to use Indian indigo. Initially, in Europe it was used only in small quantities to heighten and deepen the blue color obtained from woad, which was the only dye used in Europe to obtain blue colour. Woad was cultivated and manufactured in Germany, France, Prussia, Italy and England. Towards the end of the 16th century, European dyers began to understand that indigo was both economical and of superior quality than their woad.

In the 13th century Marco Polo recorded having seen it at Colium (an ancient port in the native state of Travancore) when he says, “they also have an abundance of very fine indigo (ynde)” (Watt 1890 IV: 391). Marco Polo’s comment confirms that he had, for the first time, seen indigo being used for dyeing blue in India. At that time in Europe, its use for extracting blue was not known, while in India it was already used for extracting and dyeing blue in a large scale.

Before the discoveries new commercial route to India via Cape of Good Hope in the 15th century, indigo reached Europe by the overland route via the Persian Gulf and Alexandria.

However, after sea routes were established, indigo was brought to Europe by Portuguese merchants along with other eastern products.

Portugese traders also supplied Indian indigo to the dyers of Holland who were the most famous in Europe,. But difficulties with Portugal forced the Dutch to procure their indigo supplies directly from India. For this purpose The Dutch East India Company was formed in 1602 which facilitated indigo export straight to Holland from India. From Holland it was supplied to all other countries. The flourishing Dutch trade provoked envy from merchants of other countries. (Watt 1890 IV)

Since Indian indigo was proved to be of better quality, it started replacing woad as a dye, slowly from 14th century when Elijah Bemiss said Indian indigo was superior to woad. But mostly in 16th century it became most sought after. In 16th century 1kg of indigo became worth 1 kg of pearls! Woad cultivators, manufacturers, and merchants faced ruined, and started a strong anti-indigo campaign, which branded indigo not only as fugitive dye, but also as a corrosive and pernicious drug. It became known as ‘Devil’s food’ and was thought to be poisonous. This strong resistance to indigo led to its prohibition in France in 1598, in Germany in 1607, and in England in beginning of 17th century.

During the time of Henry IV of France, the resistance to indigo became so strong that it in 1609 its use became a capital offence and persons found using indigo was liable for a death sentence.

Indigo and England

The first mention of indigo being used in England is found during the reign of Queen Elizabeth in 1581, where it was used along with woad. However, the method of deriving blue from indigo was still unknown. It was prohibited for a while.

Later, in 1664, the East India Company again started exporting indigo to Britain from India. By 1694 the company exported 1,241,697 lb. of indigo dye from Agra and Lahore, and 510,093 lb. from Ahmedabad. By the middle of the 18th century, the laws prohibiting the use of indigo were finally withdrawn in nearly all European countries. (Watt 1890 IV. Tolat 1980)

The demand for indigo again started increasing. It was known to be valuable enough to be paid for in pearls. This made French, Spanish, Portuguese and English colonists explore options to take up the cultivation and manufacturing of indigo themselves.

In America, in 1649, an attempt to grow wild indigo (Baptisia tinctoria) was made, but the real cultivation and manufacturing of indigo in America was started by a young girl named Eliza Lucas in 1739. By 1747, in just 8 years, she had managed to produce enough indigo to make up a shipment for England.

As the colonist of the southern part of North America and the West Indies succeeded in producing indigo of a good quality and in a large quantity, the East India Company discontinued the imports of the indigo from India. In the year 1747, however, Spanish and French colonies still continued their exports.

In the West Indies and Santo Domingo, coffee, sugar and other products were found more rewarding. Therefore indigo cultivation and indigo manufacture were abundant. By that time, British lost their colony and United State was formed as an independent sovereign. Therefore British no longer had access to indigo produce in the newly independent United States.

> *"Between 1720 and 1740 the French Company's trade increased ten times in value until it was nearly half that of the of established English company at about pound 88,000. The stake of both countries in India was now considerable. The British were deeply involved with indigo, saltpetre, cottons, silk and spices; they had a growing trade with China and a strong vested interest in England itself in shipping and stores brokers. The value of the trade was more than 10% of the public revenue of Great Britain that time. "(Spear 1990: 77)*

The British where, therefore, forced to rely on the France, Spain, and other foreign sources in Europe to meet the demand for indigo.

In the 18th century, "the company's trade had centered chiefly on cotton goods in the north and the Madras coast, with ancillaries like indigo in Gujarat, "(Spear 1990: 112)

During this time, the directors of East India Company foresaw the prospects of renewing indigo cultivation in India, thus saving British manufacturers from their dependence upon French, Spanish and Portuguese produce. The fertile soil and the cheap labour available in India only strengthened the decision to promote indigo cultivation. Active steps were taken to start indigo cultivation in Bengal. In 1779-80, the first contract for cultivating indigo and for supplying the dye was made with a gentleman in Bengal. European indigo planters were brought from the West Indies were also established in some selected districts of Bengal. Till 1788, the company did business directly in the indigo trade, invested large sums of money and executed many contracts. Great care was taken to improve the quality of indigo.

Approved samples of good quality indigo from various sources in the world were sent to India so that quality comparisons could be carried out. The East India Company continued to encourage the indigo trade by remitting their duties gradually and by giving advances to the cultivators. As the quality of Bengal indigo improved, England imported more of this variety and decreased imports from other parts of India. As the company's financial investment and attention was centered only on the Bengal trade, it flourished. At the same time, indigo cultivation in Western India, where it had originated, decreased.

In 1787, Dr.Hove, visited western India and found that indigo cultivation in Bombay had almost ceased. However, even as late as 1820 indigo was very important crop in Gujarat as evident in number of unused pits which were found near old villages and among the buried cities of Satpuda mountains.

However by 1788, even though the quality of indigo had greatly improved, heavy financial loses were sustained. As a result, it was decided that the East India Company should not purchase indigo for at least 3 years. Instead, it would allow the Company's employees and other persons under their protection to do so upon payment of the duties and charges of the Company and freight charges. This advantage was given only to the British employees.

In 1791 the board of the East India Company approved experiments at Madras, with seeds procured from Bombay. Thus indigo cultivation and the manufacturing of the dye in the state of Madras began.

As indigo started fetching good prices, the financial help given through remittance of company's duties etc. were discontinued. To make it still more independent, advances were made to Indian cultivators to encourage manufacture of indigo. This action was recorded in the comments of the board of trade of England, in their minutes of the 28 October, 1796 to the affect that the "cultivation of indigo can not be considered as decidedly established in Bengal, until the natives (Indians) can cheaply manufacture it in the quality fit for the European market." (Watt 1890 IV)

As the indigo started fetching the higher price and as the demand for indigo increased, many indigo manufacturing factories opened up in India. Indigo manufacture now spread northwards. European manufacturers started production in Benaras, Oudh and in Bihar.

The general demand for indigo was equal for fine, medium and ordinary qualities. Fine quality was almost exclusively demanded by Spain, who had always been remarkably attentive to quality. Medium qualities were almost all supplied to the French, whose products were later replaced by the indigo produce in Bengal. The ordinary quality mainly went to America.

The Decline

Indigo production had experienced temporarily declines from time to time due to political upheavals and rules imposed by various countries to protect the interests of woad cultivators of their countries. However, an irreversible decline in indigo crops started from 1914 onwards after chemical indigo started replacing natural indigo.

As the demand for indigo grew, European and Indian factories multiplied until it reached a stage that over production would cause in falling prices. Oudh, Agra and other provinces of north India dumped inferior qualities of indigo entered into the market alongside the higher quality of indigo from Bengal. This started to damage the company's good name. To discourage cultivation of inferior quality and to allow the benefits of trade to remain with the English rather than Indians, extra transit duties were levied on the indigo coming from the provinces not under the rule of East India company.

In 1776, the British market was over stocked due to the eagerness to export. In 1797, excessively eager competition between various manufacturers of Bengal and Oudh, combined with successive bad seasons and other factors, all resulted in exports from India being reduced to less than half of earlier year export. This was in spite the preference of Indian indigo throughout Europe, though stocks had accumulated from previous years imports. Exports from England to other countries increased in 1797. Indian indigo was preferred throughout Europe.

In Madras, after the trails made on Indigo seeds were approved in 1791, remittance of duty at Madras and reduction of duty to 2.5% from 5% in England was granted in 1792. By 1798, encouragement was given to Indian, to take up the cultivation and manufacture of indigo. But whether to allow for new indigo factories in Madras or not always remained a debatable point. This is because there was a fear that it might completely overstock the market in England. However, as Madras Province was also under the East India Company's rule and endowed with a suitable soil and climate, it would have been unjust not to encourage indigo production there. So the East India Company continued to allow indigo manufacture in Madras province.

But gradually by the year 1837, difficulties arose between Jamindars, planters and the actual cultivators. As the indigo trade had now been established firmly, the East India Company now started to withdraw official support and encouragement. The planters and Jamindars, therefore, started giving advances to the cultivators on a land tenure system in place of East India Company.

Due to heavy competition in India, prices in the London market fell by 35% while the value of all other crops steadily improved. However, due to the land tenure system, cultivators were compelled to grow indigo and sell it at a fixed lower price. In 1830 a law was passed making failure to fulfill contracts subject to criminal prosecution. This law left cultivators totally at the mercy of the planters. This law was repealed only in 1835.

"Complaints of enforced cultivation of an unprofitable crop on the one hand and of the want of protection against the dishonest cultivators on the other hand became rife." (Watt 1890 IV: 397) According to the lieutenant Governor of Bengal, the fault lay more in the land tenure system than with the planters. The extremely inadequate price paid for indigo cultivation was entirely unprofitable to the cultivators, which was one of the reason leading to total abandonment of the manufacture from Bengal. It also led to many other evils connected with the indigo trade. The Governor believed that the chief fault lay in the defective and the partial administration of the law, which allowed such a vicious state of affairs to exist. In 1867-77 difficulties also arose in Bihar. This led to the Champaran movement. Champaran Movement was an agitation by the farmers against forced cultivation of indigo imposed by indigo planters.

Production leaves Bengal

As a result of these disturbances in Bengal, the indigo industry chose to migrate out. Though in quality Bengal indigo was most superior, Bihar, the North West Provinces and the Madras province produced a higher quantity of indigo. Among the other reasons for this shift was the willingness of the cultivators in Madras and Northern India to grow indigo since in these regions, it did not conflict with the other cultivation. On the other hand it improved the food crop along with which it was grown in rotation. Due to this improved fertility of the soil and the gradual removal of import/export duties and taxes on green indigo plant from 1875 to 1882, trade was further encouraged. It also increased the production of indigo in Madras province as high as 68 % within the span of 32 years from 1855 to 1877. Cultivation started expanding in the canal irrigated areas and factories owned by Indians and the cultivators themselves also increased in numbers.

Chemical Indigo Ends the Show

However, in 1856, Sir Henry Perkins, an English chemist, prepared the first coal-tar-derived (aniline) dye. This was the beginning of synthetic dye, which led ultimately to the development of chemical indigo. In 1870, German chemist Adolph Von Bayer and Emmerling succeeded in producing indigo tin which is the essence of indigo dye. By 1878, Bayer further synthesized indigo but it was still more expensive than natural indigo.

In 1890, details of Herman's synthesis of indigo from Phenyglycocal were published. In 1893, Kalle & co. introduced their indigo salt in the market. This involved a simpler method of dyeing. In 1897, artificial indigo under the name of "indigo pure" was introduced in the market by Badische Aniline und Soda-Fabrik. Indigo extracts, the dyes

derived from coal-tar and the other chemical dyes like Prussian blue were also invented and used to dye fabric blue.

Bayer's discovery proved so revolutionary that India, which in the 1880s had 1.4 million acres devoted to cultivation of indigo plant, saw this sinking up to 21400 acres by 1912.

Prior to World War I, Germany, through control over intermediaries, extensive patent rights and other means, maintained a substantial monopoly of the dyestuff industry including the production of indigo.

During World Wars I and II, due to the shortage of synthetic dyestuffs, indigo cultivation received a brief stimulus. However, this was short-lived and as more inventions and manufacturing of chemical blue dyes of various sorts started taking place, the foreign demand for Indian indigo declined. Not only this, but chemical indigo and other synthetic chemical dyes slowly penetrated into India, replacing the consumption of the natural indigo which was locally produced.

Thus the indigo trade of India, which once enjoyed the monopoly throughout the world, was ruined as will become clear in the following chart showing area under cultivation and production of dye.

Years	Area (1,000 acres)	Production of Dye (1,000 cwt.)
1896-97	1,688.9	168.7
1913-14	127.6	26.8
1918-19	292.0	48.6
1929-30	75.7	14.4
1934-35	59.6	10.2
1939-40	38. 3	5.3
1943-44	57.1	9.0
1948-49	30.0	4.9
1953-54	11.7	1.2
1954-55	11.1	2.7
1955-56	10.6	2.6

(Wealth of India Raw materials 1956, Tolat 1980:33)

Present Situation.

In 1980, I documented indigo cultivation, manufacture and dyeing processes as practiced in South India. In South India, the Indigofera tinctoria plant is still cultivated and is used for producing indigo cakes. Later in 1984 I documented cultivation and manufacture of indigo from Assam Indigo (Bapicacanthus cusia) plant and dyeing processes using it among 16 different tribes of North-Eastern states of India. Presently, these are the only two reigns of India where indigo cultivation still exists.

In 1994-95 I helped a company to export 6 tons of indigo from India. Now with demand for eco dyes and fabrics, indigo should have a brighter future provided it is taken up in an organized way.

To revive the indigo trade, I have personally carried out research and experiments in extracting and dyeing using indigo. I have also designed collection including various resist techniques used along with indigo dyeing. I have also experimented with indigo dyeing and got yellow, light green, light and turquoise blues, pink and purples using indigo.

My solo exhibitions, ‘The Blue Wave’ and “Indigo’ held in Tokyo, Delhi, Ahmedabad, Mumbai, were attempts to create various, never explored directions for various visual effects which could be achieved using indigo.

Ch. 13

‘Textures of ‘Wootz’:
Techno-cultural insights on steel and ferrous metals in South Indian antiquity

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“there is a cake which is supposed
to be steel from India and the kind
to be rated most highly in Egypt.
I could find no artisan in Paris
who succeeded in forging a tool out of it”.

-Rene Antoine Ferchault de Reaumur,1722
cited by A.G. Sisco and C.S Smith 1956

Introduction

In antiquity, India had been a world leader in producing high grade steel several hundred centuries before comparable steel came into vogue in the West. European travelers in the 17th century observed cakes of steel being made in the southern Indian states of Andhra Pradesh, Karnataka and Tamil Nadu. The steel was known in local languages of the region as ‘ukku’ which theytermed ‘wootz’. The novelty of ‘wootz’ lies in the fact that it was a high carbon steel with 1-1.5% carbon, whereas previously Europe had only been familiar with low-carbon steel.

Indian wootz steel was especially sought after across the oceans in West Asia to make a naturally wavy-patterned sword blade, which resulted from forging and etching a wootz ingot: the fabled ‘Damascus’ blade which was as beautiful as it was devastating. Celebrated writer Walter Scott in his book, ‘The Talisman’, memorably fictionalised an encounter going back to the 12th century Crusades between King Saladin of Egypt and King Richard of England where Saladin sliced a pillow with his superior Damascus steel blade. Perhaps no other material of antiquity has been as much feted over the ages through literature, films, and in recent times, the internet as wootz with its synonymous terms of Damascus steel, Bulat and Ondanique, derived from the Arab term ‘Hinduwani’ meaning Indian steel.

Quite apart from its historical significance, wootz steel has a special place in the annals of materials science as the interest taken in wootz by 18th-20th century experimenters in Europe sparked off several pivotal early developments metallurgy with no less than Michael Faraday, renowned inventor of electricity, having studied it. Even in the realm of modern metallurgy, ‘wootz’ as a high-carbon steel has attracted interest as an ‘advanced material’ with interesting properties in the fields of superplasticity and nanomaterials.

The mystique of wootz and Damascus steel has spanned the realms of both art and technology with the patterns of the 'Damascus' blade made of wootz having been compared to the texture of silk. By analogy, the book, 'Textures of Wootz', aims to the explore the many facets of wootz steel, which forms an important part of India's scientific heritage, within the backdrop of a technological-cum-cultural overview of ferrous metals and particularly high-carbon alloys in Indian antiquity. The introductory chapter 'Exploring paradigms of innovation within the Indic tradition' touches upon the relevance of integrated techno-cultural approaches in gaining insights into Indian material culture including wootz steel.

The Genesis of 'ukku'

The second chapter to the book entitled "Genesis of 'ukku': Insights from megalithic ferrous metallurgy, high-tin bronzes and crafts" aims to explore the background to the development of ferrous and non-ferrous metallurgy, particularly in southern India, that may have contributed to the emergence of the specialized wootz crucible steel technology. One of the best known legends is that ofAlexander being presented 100 talets of 'bright Indian iron' by the defeated Indian king Porus sometime around 320 BC.

The term 'ukku' may derive from 'uruku', used to describe fused or melted metal in Tamil Sangam literature dated broadly from about the 5th century BC to 5th century AD, The moving bardic Tamil poems of the remarkable poetess Auvaiyar are particularly evocative of the skirmishes with spears between rival chieftains of that era. Accounts of the Greek Zosimos of the early Christian era suggests that the Indians used crucible processes to make metal for swords, i.e. steel. Pliny's 'Natural History' talks of iron from the Seres which may refer to the ancient south Indian kingdom of the Cheras who are referred to in Sangam texts. Much still remains much to be investigated and clearly established concerning the antiquity of wootz steel in India and on the identification of ancient artifacts of wootz. Nevertheless, it is significant that there is a mention in early excavation reports of two javelins with 1-2% carbon from megalithic sites of the first millennium BC in Andhra Pradesh in southern India (Sundara 1999); although further investigations with micro-structural evidence are probably required to ascertain if these can be taken as conclusive evidence for wootz steel. Investigations by the author on a crucible fragment from the megalithic site of Kodumanal, Tamil Nadu (3rd century BC) excavated by K. Rajan, Tamil University, found in an iron smelting hearth showed it to be iron-rich without any other significant metal, which did not rule out the fact that it could belong to some kind of ferrous process although as yet no clear evidence of metallic remnants could be found in the crucible (Srinivasan and Griffiths 1997).

This chapter also touches on the general background and technological parameters within the context of peninsular megaliths and the southern Indian region which could have supported more advanced metallurgical skills. Aspects of megalithic iron technology are explored. Apart from the interesting early finds of iron from sites such as Hallur, dated to the late second millennium BC, significant iron smelting furnaces have been excavated at megalithic sites such as Guttur in Tamil Nadu and Naikund, from the Vidharbha

megaliths of Maharashtra. Recent excavations on early historic sites such as Peddabankur in Andhra Pradesh have provided rich finds of iron. Previously the Indian subcontinent had not been associated with a more sophisticated bronze working tradition. However, metallurgical investigations by the author established for the first time the use of specialized alloys known as high-tin beta bronzes (which are quenched binary copper-tin alloys bronzes of around 23% tin) to make vessels going back at least to the iron age burials megaliths of the early first millennium BC of the Indian subcontinent. These rank amongst the earliest of such alloys known in the world, and which are still made in parts of India such as Kerala by similar processes as reported in Srinivasan (1994b, 1997, 1998a) and in papers written by the author with Ian Glover while at Institute of Archaeology, London (Srinivasan and Glover 1995, 1997). High-tin beta bronzes generally do not seem to have been in vogue in Europe, and indeed the Greek Nearchus (4th century BC) mentions that Indians used golden vessels which shattered when dropped which may be interpreted as high-tin bronze, as suggested by Rajpitak and Seeley (1979). What is significant is that the processes of quenching high-tin bronze indicates a general familiarity with heat treatment processes in the megalithic period that could have extended to the knowledge of iron and steel metallurgy. Other evidence for skilled metallurgical activity comes from evidence suggesting that the deepest old gold mine in the world comes from Hutti in Karnataka with carbon dates from timber collected from a depth of about 600 feet from a mine going back to the mid 1st millennium BC (Radhakrishna and Curtis 1991).

Wootz as high-carbon Crucible Steel

The chapter 3 is entitled " 'Wootz' as high-carbon crucible steel: Evidence from southern India' which aims to look at the archaeometallurgical evidence and other literary records mainly from the medieval period. Arab records mention the excellence of Hinduwani or Indian steel while the 12th century Arab Edrisi mentioned that it was impossible to find anything to surpass the edge from Indian steel. Records indicate that Jewish merchants of the 11th-12th century from Cairo imported iron and steel along with prized metal vessels from southern India. Late medieval observers of the manufacture of wootz steel in India have commented on the process of carburisation of iron to steel in crucibles where a batch of closed crucibles which were packed with a low carbon iron charge were stacked in a large furnace and fired in a long 14-24 hour cycle at high temperatures of not less than 1200°C in a strongly reducing or oxygen-deficient atmosphere.(Percy 1860-1880; 773-776).

European travelers and geologists such as Taverner, Buchanan, Percy and Voysey from at least the seventeenth century onwards have described the production of 'wootz' steel ingots by crucible processes over large parts of southern India, such Golconda in Andhra Pradesh, the former Mysore state (in Karnataka) and Salem district in Tamil Nadu. The processes adopted over these different sites also varied a bit. The so-called Mysore process seems to have involved the making of high-carbon steel by carburising low-carbon wrought iron (<0.04% carbon) by heating it with carbonaceous material such as leaves and stems. The Deccani process associated mainly with the Hyderabad region is thought to have involved the co-fusion or heating together of wrought iron and cast iron

(usually 4% carbon) to get a high-carbon steel of intermediate composition (1-2% carbon). Thelma Lowe has most extensively surveyed and studied Deccani wootz crucible steel processes from the region of Konasamudram in Andhra Pradesh while, following K.N.P Rao's pioneering studies, Martha Goodway and Paul Craddock have also examined the wootz production site of Gatihosahalli in Mysore. Significantly, the author identified from surface surveys three previously unknown sites for crucible steel production in southern India at Mel-siruvalur in Tamil Nadu and Tintini and Machnur in Karnataka. Crucibles from one of these sites, Mel-siruvalur in Tamil Nadu shows clear evidence for the production of a hyper-eutectoid (1.3% C) steel, i.e. a high-carbon steel, made by carburisation of wrought iron apparently reaching the molten state at high-temperatures (Srinivasan 1994, Srinivasan and Griffiths 1997). Interestingly the micro-structure matched well with that of laboratory simulated ultra-high carbon steels which exhibit superplasticity, whereby considerable plastic deformation can be achieved at high temperatures . Significantly, the site also shows signs of megalithic occupation in the vicinity as independently verified by Sasisekaran (2002) while the author found numerous remains of what appeared to be legs of megalithic sarcophagi in a dried up canal near the dump. The megalithic period in southern India ranges in different places from the early 1st millennium BC to early centuries AD.

This chapter also attempts to place the general process metallurgy of wootz within the context of other Indian technological traditions. To take an example, the nearly sealed crucible process, described in texts like the *Rasaratnasamuchaya* and also used for wootz steel production, is reminiscent of 11th century zinc smelting retorts from Zawar in Rajasthan from where the earliest known remains from zinc smelting are found. Lead isotope analyses undertaken by the author on a zinc ingot with a 4th century Deccan Brahmi inscription (previously exhibited in Science Museum, London, courtesy late Nigel Seeley) corroborated a likely Andhra Deccan provenance, making it one of the earliest known surviving examples of metallic zinc in the world (Srinivasan 1998). Thus one could argue for similarities in the inspiration behind zinc smelting and crucible steel production. The closed-crucible process is still used in a traditional process of making mirrors of a specialised 33% high-tin delta bronze alloy investigated by the author from Aranmula, Kerala (Srinivasan and Glover 1995). In that sense one could argue for contiguities in various Indian metallurgical traditions.

Shades of Swords

The chapter 'Shades of swords: From 'Damascus' blades to martial arts swords of Kalaripayattu' explores some of the blade making traditions associated with wootz steel studies on the replication and properties of Damascus swords and ultra-high carbon steels. Accounts indicate that at least by the 16th-17th century, south Indian wootz steel was reputed to have been used to produce the famed 'Damascus' blades, which have an artistically appealing pattern due to the etched crystalline structure of forged high-carbon steel, of which surviving Persian, Indian, Arab, Indo-Persian and Turkish examples are well known. The 'Damascus' blades, so named after one of the best known sword production centers, can be clearly identified as having been made of high-carbon 'wootz' steel due to the their wavy patterns caused by the above mentioned etched crystalline

structure. Recent interesting studies have been made on wootz steel, for example by J.D. Verhoeven and Alfred Pendray in experimental re-constructions and forging of Damascus blades who suggest that the banded pattern of the etched blades resulted from the presence of traces of vanadium in Indian wootz steel. In other landmark studies, Oleg Sherby and Jeff Wadsworth showed the ultra-high carbon steels of a composition similar to wootz exhibited properties of superplasticity and won a patent for such steel which was already an advanced material from Indian antiquity.

Compared to Damascus steel, also known as watered steel, far less is known about other types of traditional Indian swords and implements as to whether they were made from wootz or high-carbon steel or other processes. This chapter touches upon lesser known aspects about Indian armoury and examples of watered steel blades from Islamic and Hindu contexts including Mughal armoury, Rajput armoury, Maratha armoury, Tipu Sultan and Mysore armoury, Tanjore armoury and Nizam's armoury, apart from the swords from Telengana etc. Another neglected area that is explored in greater detail is the use of weapons in martial art traditions in India such as the Kalaripayattu, originally a Hindu martial art tradition practiced by the Nairs of Kerala. Studies by Zarrelli suggest that the skilled Kalaripayattu tradition may go back to the martial traditions of the Tamil Sangam era of the early centuries AD and is linked to the Tamil siddha form of medicine. Investigations by the author on novel flexible swords used in the Kalaripayattu tradition of the Malabar show them to be of spring steel which is also points to the unique metallurgical skills of the region.

Emergence of Cast Irons in Indian Antiquity

The chapter 5 is entitled 'Re-examining the questions of emergence of cast irons in Indian antiquity'. An interesting question that has received little attention but is related to the development of wootz high-carbon steel is whether cast iron was ever made in Indian antiquity. Of course, it is well recognized that cast iron first came into widespread use in China much before Europe or other parts of the world, where it was widely used by the early christian era for a range of artifacts including some monumental castings. In the Indian subcontinent, cast iron is thought to have only came into vogue very much later from the late medieval period; for instance cast iron pillars were used for the first time in architecture in the Mysore palace made in Britain. It is intriguing however, that there are reports of some evidence for production of cast iron with about 6% carbon from a megalithic period twin hearth furnace in Guttur in Tamil Nadu (dated c. 500 BC) (Sasisekaran 2002). Recent excavations by University of Michigan at Kadubakele, a megalithic site carbon dated to 800 BC, revealed intriguing iron rings. It is questionable if the method of manufacture was forging for these rings. Similarly, iron bells are also reported from megalithic contexts. It has also been observed that some crucible steel processes resulted in the production of white cast iron. Large iron furnaces have also been reported from the Malabar from the colonial era from where fine traditional iron lamps are known, while iron cooking utensils are still used widely in the south. In Kerala, till recently, a special type of iron wok was used for cooking, known as chinachetti, suggesting Chinese influence. Thus, there are interesting facets to be explored in connection with the emergence or use of cast iron.

Ferrous Arifacts from Decorative and non-Weaponry Contexts

The chapter 6 entitled 'Ferrous artifacts from decorative and non-weaponry contexts' touches upon the history of use of ferrous artifacts in a range of decorative and utilitarian uses as well as links with other arts or crafts. The best example of the decorative use of iron from the Indian subcontinent is of course the corrosion resistant Gupta era Delhi iron pillar (4th-5th century) which is the largest known early wrought iron forging. It is also true that massive forged architectural iron beams were used in the medieval Konarak and Jaganannath temples in Orissa.

However, the use of iron in figurative or decorative contexts is less known which this chapter delves more into. For example, a tiny ferrous mother goddess figurine was uncovered from megalithic Alangankulam in Tamil Nadu, dated c 1000 BC. India has a rich tradition of stringed musical instruments: from the traditional veena used in the Hindu devotional Carnatic music style of southern India, to the Indo-Islamic adaptation of the sitar in northern India (which owes its name to the Persian instrument). Accounts suggest that wire for the Persian sitar was traded out of the 15th century Vijayanagara kingdom of Karnataka, with the musical stone pillars of Hampi corroborating the kingdom's grasp of the science of music. Chennapatna near Mysore was famed for its steel-wire drawing used in the making of musical strings according to colonial accounts, while traditional centers for making the stringed instrument of the veena survive in Chennapatna and Tanjore.

From Iron Age and megalithic contexts, interesting utilitarian artifacts made of iron are found such as ladles, tripods, lampstands from Adichanallur, wire-frame cubes from Mahurjhari etc. Figurative iron amulets are also known such as from early historic Kadubakele in Karnataka. The early historic site of Peddabankur in Andhra Pradesh yielded interesting material such as iron scissors. Thus the topic of utilitarian and non-weaponry finds of iron is an interesting one.

Continuation of the Blacksmithy Tradition

The chapter 7 entitled 'Continuing traditions and social history of iron smelting and blacksmithy' touches upon aspects of the social history of ferrous metal artisans, surviving traditions and aspects of continuity and change. Traditionally, iron workers belonged to the artisan community known as Viswakarma, while *Manu,* who worked in iron is said to have been the first of the five sons of *Viswakarma*, the maker of the universe. Nevertheless, as far as actual social hierarchy goes, today the rural blacksmith has slipped to the bottom of the social status among artisans. Since the artifacts produced by blacksmiths are utilitarian and often do not receive support as handicrafts, there is a danger of them being marginalised. A study of the social history of metal artisans throw up interesting insights such as the interesting case of the legend of Munishwara, a metalworking saint, to whom there are several shrines in Karnataka who is said to have been revered by Hindus and Muslims alike. Indeed, from technical investigations the

author found evidence for both crucibles related to wootz steel production and copper smelting slags from a shrine to Munishwara in Tintini, indicating that the story was associated with actual metalworkers. Thus, the illuminating aspects in the social history of rural blacksmith and continuing traditions deserves to be presented.

Wootz Steel: Global Perspectives

The concluding chapter 8 is entitled 'Wootz steel: global perspectives'. Apart from the literary and cultural evidence, preliminary archaeometallurgical evidence from south Indian megalithic contexts also suggests that the origin of high-carbon wootz steel made by crucible processes seems to come from the southern Indian peninsula. In recent years, concerted archaeometallurgical studies have brought to light evidence for steel made from crucible processes in other parts of Asia, including Merv in Central Asia and also Sri Lanka, which had its own skilled iron working traditions thought to date from the end of the first millennium AD. However, studies have yet to be able to clearly establish if the end-products at such sites were high-carbon steel. This has broadened the global interest in the subject, while the fine examples of Damascus steel in Persian, Arab and Ottoman collections have been often been the subject of museum exhibitions or books in the west.

The story of the role that wootz steel played in spurring 18th-20th Europeam scientists towards several innovations that laid the foundation of modern metallurgy is remarkable in itself. Indeed, Cyril Stanley Smith ranked Damascus steel amongst the four outstanding researches in metallurgical history. The topic of wootz/Damascus steel has resonance even in modern scientific contexts such as nanotechnology as further elucidated in the book, 'India's legendary wootz steel: An advanced material of the ancient world' (authored by Sharada Srinivasan and Srinivasa Ranganathan, 2004), while the attempted replication of Damascus blades still has a large following as indicated by numerous websites. Some of these aspects related to the global ramifications of wootz/Damascus steel to science, art, culture and literature are summarized in this concluding chapter.

Ch 14

Colonial Destruction of India's Textile Industry

Rajiv Malhotra and Jay Patel

Charles Grant, an influential historian and servant of the East Indian Company *"commented explicitly on deficiencies in Indian science and technology, which he linked to overall defects in Hindu civilization. He conceded that the Indians had made advances in a variety of forms of handicraft manufacture, but he argued that these had been achieved in an age long past and that there had been little improvement in Indian techniques in thousands of years. Grant contrasted the Hindus' superstition and lack of curiosity with the "great use" that the British and other Europeans had made of reason "in all subjects" and the manner in which European scientific discoveries complemented, rather than competed with, Christian beliefs. He argued that the Indians were ignorant of the natural sciences and that "invention seems wholly torpid among them." He boasted that the superiority of Europeans' understanding of the natural world could readily be demonstrated by the "sight of their machines."*

James Mills, author of the landmark *History of British India,* believed, *"the Indians had advanced beyond the first and lowest stage of social development but had never been "truly" civilized-a level of refinement that he believed had been attained only by the ancient Greeks and the Europeans since the Renaissance. He thought India roughly comparable to medieval Europe, though inferior to the latter in agriculture, the arts and intellectual attainments. Central to his low estimate of both Indian and medieval European achievements was his conviction that they had contributed little to scientific thought and technological advancement."*

("Machines as the Measure of Men," by Michael Adas pp. 166-168)

These types of accounts have been the fuelling the intellectual discipline of imperial history-making, a discipline in which the West is surely a pioneer. This narrative assumes that prior to colonial intervention the East lived in utter depravity, and in a static state of societal, economical, and cultural barbarity. In particular, the East was seen as caught in a primitive vacuum that begged for Western intervention, including regime changes. In contrast, the West was the self-declared center of superiority, modernity, sophistication, and, of course, scientific genius. Sadly, this mindset is still deeply ingrained, but when the historical facts are examined objectively this narrative becomes untenable.

To illustrate this point, the following chapter will provide a case study of the Indian textile industry of pre-1850 India. According to Paul Bairoch, by 1750 the Indian subcontinent accounted for approximately 25% of the world's manufacturing output of which textiles was the most important sector.[i] However, these historical facts challenge the colonial discourse and thus are conveniently ignored or not given prominence. This chapter will examine the colonial role in the destruction of the textile industry and the subsequent historical distortions that still haunt the Indian psyche to this day.

The Legacy of Indian Textiles:

India's textile exports are legendary. Since the times of the Roman Empire, India and China had been world leaders in cloth exports. The Roman archives contain official complaints about massive cash drainage because of imports of fine Indian textiles. The Indian cloth was of the finest quality and cheaper than its competitors.

This Indian domination in the textile trade continued up to the arrival of the East India Company from England. British traders brought Indian cloth to England, exploding the consumer market with this finely crafted, sophisticated, and beautiful foreign cloth. By 1620 CE, 50,000 pieces of chintz reached the British markets and by 1720 CE India was exporting 600,000 pieces to Britain.[ii] There was a great amount of wealth associated with the trade of textiles and proved to be a lucrative commodity. The Dutch trading company, the British's most fierce competitor, was also heavily involved in the Indian textile exchange.

At the end of the seventeenth century, goods procured in Bengal alone - the principal Asian supplier of textiles and raw silk sent to Europe - accounted for as much as 40 percent of the total Dutch exports to Europe value wise. If goods procured in the three other principal Indian regions - Gujarat, the Coromandel coast and the Malabar coast - are added to the Bengal cargo, this proportion goes up to as much as around 70 percent. (*"Indian-Studies in the History of an Idea". Seventeenth- Century India as Seen by the Dutch"* by Om Prakash. Irfan Habib. 2005. pg 144-158.)

Claude Alvares, in his book *Decolonizing History*, states that before the East India Company arrived in the sub-continent, there was nothing produced in Europe which India needed, because the consumer goods produced by Indian industrial techniques were of higher quality and less expensive than the goods offered by European suppliers. A huge trade deficit in India's favor was the result of this unilateral demand, which greatly alarmed the British. In fact the whole of Europe was reluctantly forced to use their precious metal reserves in order to finance the trading.

Over centuries, and indeed millennia, the principal commercial interest of the Europeans in Asia had been the procurement of spices such as pepper, cloves, nutmeg, mace and cinnamon and other luxury goods such as Chinese silk and Indian textiles. For the simple reason that Europe had traditionally been unable to supply western products with a potential market in Asia at prices that would generate a large enough demand for them to provide the necessary revenue for the purchase of the Asian goods, these goods had always been paid for overwhelmingly in precious metals. Considering that wealth had traditionally been associated exclusively with precious metals, this particular pattern of trade had persuaded authors such as Gibbon to complain that in return for trivialities, Europe was allowing itself to be bled by Asia. ("Indian-Studies in the History of an Idea". Seventeenth- Century India as Seen by the Dutch" by Om Prakash. Irfan Habib. 2005. pg 144-158.)

By 1700, England (today's grand flag-bearer of free trade and open markets) imposed a £200 penalty for wearers or sellers of imported cloth in order to curb this trade imbalance. By 1720, they imposed a prohibition on Indian cloth, even invoking the Christian sentiment by declaring the outlaw "the passion of ladies for their fashion".[iii]

… the English Prohibition and Sumptuary Laws of 1700-1730: "The use of printed Indian cloth and calicoes both in apparel and household furniture was at this time so universal as to be a great detriment and obstruction to the woolen and silk manufactures of the kingdom. This had occasioned several riots and

tumults of the weavers in London. It was therefore found necessary to redress the grievance wherein so many were interested. An Act of Parliament was in consequence passed to preserve and encourage the woolen and silk manufactures. It absolutely prohibited the wear of Indian cloth under the penalty of £5 for each offence on the wearer and £20 on the seller." ("The Ruin That Britain Wrought", by K.M. Munshi pg 6-7)

The textile industry had larger implications in this era of global commerce. It was intimately linked to many other sectors of the Indian economy. India's dominance in the textile trade directly boosted its performance in other sectors such as agriculture, machinery, and finance.

A main locus of the industrial revolution of course was the textile industry. We have already observed the Chinese, Persian, and Bengali world economic preeminence in silk and Indian predominance in cotton. They were the highest-quality and lowest-cost producers in the manufacturing industries, competing even more successfully worldwide than in armaments and shipbuilding… textile production also had widespread linkages to the agricultural, machinery, transportation, vegetable dye and mineral-derived chemical industries, not to mention finance. To be a high-quality/low-cost producer and seller of textiles, competitive production in and coordination among all these ancillary industries was necessary. India excelled in all of them. (Chapman 1972: 12 from "*Reorient: Global Economy in the Asian Age*" by Andre Gunder Frank)

In addition to these legal measures to disrupt global free trade, increased pressure was put on British domestic cotton industries to produce better quality and cheaper cloth. In fact, British textile producers attempted to market their cloth as "made in India" - a mark of superior quality. Eventually, mechanization was needed in order to produce the same quality of cloth at a cheaper price in England. However, by this time colonial rule had thoroughly depleted the competitiveness of India's industries and reduced them to cash cows under colonial control.

This parallel seizure of industry and markets by the British was explicit and extreme. As early as 1669, Gerald Ungier, a factory chief in Bombay, wrote to the directors of the East Indian Company declaring, *"The time now requires you to manage your general commerce with the sword in your hands".* To police its industrial and financial interests, the military presence of the British grew rapidly in the territories they had annexed in India and by 1803 the British had 130,000 armed Indian sepoys in their service.[iv] The iron first of colonial rule was thus integral to reshaping the Indian economic situation. In the end, Indian manufacturing was destroyed and forgotten, and the Indian consumer market was taken over by what started out as inferior British goods.

Indian Labor Misportrayed as Poverty-Stricken and Exploited:

The popularity of Indian cloth in England and Europe was met with great disdain from European manufacturers. But the British could never admit that Indian manufacturing excellence was due to India's superior system of labor, organization and technology. Colonial arrogance prevented such acknowledgment. They had to rationalize how Indian cloth was both cheaper and of higher quality than the European product. Hence, the British began a campaign to claim human rights and labor abuses in India as the reason for its competitive advantage. The following set of quotes is a mere sample to illustrate what became a widespread portrayal of Indian society in England:

"China, India and other Eastern Countries ... have, it is true, the most extended manufacture, and the greatest variety in the world... But the people who make all these fine works are to the last degree miserable, their labour of no value, their wages would fright us to talk of it, and their way of living raise a horror in us to think of it: Their women draw the plough instead of horses; their men perish and sink under the weight of their heavier labour, because the food they eat is not of sufficient nourishment to support them, and the wages they get cannot provide better food for them; and yet their rigorous task-masters lash them forward as we (cruelly too) sometimes do our horses." ("*A Plan of the English Commerce",* Daniel Defoe, London, 1728. Reprinted Oxford, 1928, 49-50. As cited in "Rethinking Wages and Competitiveness in Eighteenth Century: Britain and South Asia", Prasannan Parthasarathi, Past and Present, 158, pg. 79-109. Feb. 1998)

John Basset, speaking in parliament, criticized the importation of Indian cottons on the grounds that *"people in India are such slaves as to work for less than a penny a day, whereas ours here will not work under a shilling".* ("*Chronicum Rusticum-Comerciale*", John Basset, ed. John Smith, 2 vols. (London, 1747), i, 351 as cited in Parthasarathi, 1998)

According to Francisco Pelsaert, who journeyed through the Mughal Empire in the early 17th century, *"There are three classes of the people who are indeed nominally free, but whose status differs very little from voluntary slavery -- workmen, peons or servants, and shopkeepers. For the workman there are two scourges, the first of which is low wages ... The second is [the oppression by] the Governor, the nobles, the Diwan, the Kotwal, the Bakhshi, and other royal officers. If any of these wants a workman, the man is not asked if he is willing to come, but is seized in the house or in the street, well beaten if he should dare to raise any objection, and in the evening paid half his wages, or nothing at all."* ("*Jahangir's India*", Francisco Pelsaert, trans. by W. H. Moreland and P. Geyl, Cambridge, 1925, 60. Also see Moreland's, India at the Death of Akbar, 265-70. as cited in Parthasarathi, 1998)

Mrs. J. Kindersley, another traveler to India, wrote in 1765 that Indian workers *"…are poor indeed; scarce any covering, their food rice and water; their miserable huts of straw…; no liberty, no property, subject to the tyranny of every superior.* ("*Letters from the Island of Tenerife, Brazil, the Cape of good Hope and the East Indies*", Mrs. J. Kindersley, 1777 no. 43. cited in Tapan Raychaudhuri, `The Mid-Eighteenth-Century Background', in Dharma Kumar and Tapan Raychaudhuri (eds.), The Cambridge Economic History of India, ii, c.1757-c.1970 (Cambridge, 1982), 8)

This type of profiling left its legacy in the colonized world. Even today, the typical image of an emaciated, dejected "victim" is portrayed as the quintessential Indian laborer. The British propaganda-makers successfully painted a picture of horrid worker conditions for Indian workers, subjugated by India's ruling elite. This sentiment echoed well in the political climate of liberal Europe, which was in the emerging stages of the philosophy of human rights. In post-Marx Europe, the historical account has been twisted into an even more abstruse, yet widely prevalent account of class struggle. In the 1920s W.H. Moreland, a leading historian of Indian economics, believed that

"at the opening of the seventeenth century, the population of India consisted of a small but extremely wealthy and extravagant upper class, a small and frugal middle class, and a very numerous lower class, living generally on the same plane of poverty as now, but on the whole substantially worse off". ("*From Akbar to Aurungzeb"*, W H Moreland, London, 1923, New York reproduced 1975; 197-8, as cited in Parthasarathi, 1998)

Many Indian scholars, such as Tapan Raychaudhuri[v] and K. N. Chaudhuri[vi], dutifully echoed this condemnation of Indian society for global competitiveness in industry. The central assumption of these depictions is that the Indian governance was one of Oriental

despotism, a term branded successfully to denigrate non-white civilizations' worthiness. Ronald Inden summarizes this definition of Oriental Despotism:

> *Despotism, the arbitrary or capricious rule by fear of an all-powerful autocrat over a docile and servile populace, is the normal and distinctive political institution of the East. That elusive mode of production whereby the peasantry of the immense Asian plains, distributed over innumerable, self-sufficient villages, engages in a mixture of low grade agriculture and handicrafts, makes over to the despot the surplus of what it produces in the form of a tax, subsisting on the remainder, is, as its name Asiatic proclaims, the distinctive economic (and social) institution of the East.* ("*Imagining India*", Ronald Inden pg. 53)

This portrayal of Indian laborers, as poor and exploited, was not based on research but rather on the recorded anecdotal accounts of European travelers that were conveniently utilized by Orientalist theorists. These writers did not have the cultural sensitivity or familiarity to scientifically assess labor conditions, and imposed their subjective European biases and social constructs on to a dissimilar society. Lack of linguistic competence, ecological and environmental familiarity with the tropics, and social and cultural knowledge added to the negative European accounts. The most significant contribution to the negative portrayal, however, was the colonial arrogance and haughtiness directed at everything outside of the White/Christian tradition of Western Europe.

The colonial discourse on the Orient was certainly predicated on building a European identity in opposition to the Oriental identity. The colonial manifest destiny required that it posses all that was desirable and good and that the 'Other' posses the opposite. That which was desirable in a 'modern' society (i.e. human rights, democratic rule, social mobility, right to property, rationality etc.) was essentialized as Western and the opposite of these were essentialized as properties of the Orient. Inden again explains:

> *…Euro-American Selves and Indian Others have not simply interacted as entities that remain fundamentally the same. They have dialectically constituted one another. Once one realizes the truth of this, he or she will begin to see that India has played a part in the making of nineteenth and twentieth-century Europe (and America) much greater than the 'we' of scholarship, journalism, and officialdom would normally wish to allow…European discourses appear to separate their Self from the Indian Other – the essence of Western thought is practical reason, that of India a dreamy imagination, or the essence of the Western society is the free (but selfish) individual, that of India an imprisoning (but all-providing) caste system. But is this really so? To be sure, these discourses create a strange, lop-sided complementary between the Western Self and its Indian Other.* ("*Imagining India*", Ronald Inden pg. 3)

The working conditions and labor systems in India were denigrated, not only for justifying the imposition of European rule but also for constructing the working conditions and labor systems of Europe. The West was lauded as the harbinger and champion of workers rights, social mobility, rational and scientific thought, and

everything else signifying progress and modernity. However, it is not hard to search through the annals of European history to find abundant evidence against such an assertion (including in the textile industry as will be demonstrated below).

The Orientalist scholars concluded that a despotic, dictatorial and mercantile elite was exploiting the Indian peasantry, including the weavers and spinners of the textile industry. This is very reminiscent of the arbitrary and selective use of human rights in contemporary geopolitics, designed to justify Western intervention and hegemony. Let us now examine the facts to arrive at a more objective and historically accurate conclusion.

Indian vs. British Textile Industry: A Historical Comparison:

This section looks at the success of India's textile industry by comparing the wage rates and labor practices of India and England before the textile industry in India was dismantled and relocated to the factories of Manchester. The data and analysis in this section are based extensively on the scholarship of Professor Prasannan Parthasarathi in his work *"Rethinking Wages and Competitiveness in the Eighteenth Century: Britain and South India.*"

1) Wages:

> *"A review of the literature on historical comparisons of per capita income suggests that around 1760 disparities between now advanced and lagging countries were quite small and, once polar cases are excluded, probably nonexistent."* ("*Poverty From the Wealth of Nations: Integration and Polarization in the Global Economy since 1760*," by M. Shahid Alam P. 25. 2000)

The most obvious and direct method to compare workers' conditions in India versus England is to examine the real wage rates of the two countries. Agriculture was the largest employer, both in India and England. The textile industry in each country occupied the position of second largest employer. Within the textile manufacturing industry, spinning and weaving were the two critical processes. In both India and Britain weaving was predominantly performed by men, and spinning by women. Therefore, by comparing agriculture, spinning, and weaving wages we will more fairly be able to compare workers (both men and women) in these industries.

The real wages in the mid-eighteenth century were higher in India than in Britain. The reason for this was a combination of advantages that Indian labor enjoyed, such as shortages in the labor market, rights of contract, mobility, and a political order that was conducive to the preservation of these conditions.

Based on records in South India, if all non-monetary bonuses were included, agricultural wages would have been comparable with, if not greater than, the range found in Britain. The institution of annual contracts for labor also granted a great amount of security to Indian agricultural laborers since the employer had the responsibility to provide year-round employment. In Tanjore, the most significant rice-growing district in southern

India, this practice was maintained until the 1930s. In other cases, agricultural labor was in short supply and in several parts of South India, peasants traveled from village to village during key seasons in agricultural production. They were often lured by political and revenue authorities with offers of favorable compensation packages and working environments.

Spinners in South India appear to have had higher wages than those in Britain. The range of wages in Britain was from 4d to 2s, while in India the range was 7d to 2s. The direct comparison shows that the wages were, at minimum, comparable. However, there is reason to believe that Indian wages were indeed greater. If we consider the fact that the labor provided by the outcaste agricultural laborers of Madras earned more than English farmers in terms of real wages, we can infer that the more skilled labor was even better compensated.[vii]

The wages recorded also indicate that weavers in India were better compensated than weavers in rural and small-town Britain and comparably compensated to weavers in London. The Indian weavers were a skilled labor group, in demand, and almost always close to full employment. In 1736, an official of the East Indian Company observed this phenomenon and stated that the demand for Indian cloth was "greater than all the weavers in the country can manufacture."[viii] The market demand for cloth, in fact, provided great stability to the Indian economy and labor markets, as will be explained later.

In summary, weekly wages for male and female laborers in Indian textiles were at least comparable with their British counterparts, though evidence suggests that Indians often were paid more. In agriculture, male wages were also comparable between the two countries, and in all likelihood sometimes higher in India.

2) Market Demand:

It has been well established that the worldwide demand for Indian cloth was large and widespread. This demand ensured full employment to the community of textile workers and provided a great deal of stability.

The diversity of markets for Indian cloth exports provided insulation against market shocks. If business suffered a calamity in one or two markets, there was ample demand elsewhere to ensure stability. Consequently, this steady flow of orders secured employment for workers.

This demand created an economy of scale that gave Indian textile a competitive advantage. A significant advantage in scale is conducive to a decreased unit cost of manufacturing.

Many contemporary authorities testify to Indian industrial and commercial products of the 17th and 18th centuries. Some two hundred distinct items of cloth goods are mentioned as export specialties. Even about 1750, the East India Co., engaged the work of over 40,000 looms (about 50,000 weavers) in the South. The total number of weavers in South India was over half a million and in Bengal, a million. Philip Anderson

said "The manufactures of England could not compete with those of India." ("The Ruin That Britain Wrought", K.M. Munshi pg 6-7)

The British weavers could not sustain stable employment because there was less foreign demand for their inferior and expensive broad cloth. Market stability and economies of scale were uncommon in the British textile industry.

3) The Status of Labor in the Textile Industry:

It is widely held that Europe, especially England, was a forerunner and pioneer of labor rights and organization. However, contrary to colonial scholarship regarding caste, the labor jatis in India served as equivalents of trade unions and were in fact powerfully positioned.

For example, the weavers of South India operated as a collective body in negotiating with merchants. These collectives ranged in size from one to several villages, and they negotiated contracts, received advances, and filed complaints to merchants and governing bodies. The whole community was responsible for the completing and delivering contracted cloth; they even shared responsibility for the individual debt of its members.

In Britain, however, the labor market was much more slack and disorganized. This, of course, gave the employer the upper hand in bargaining and wage negotiation. It was only after the worker's rights movement that European workers organized themselves into collective bargaining entities. While India's jati (trade communities) secured the Indian laborer, Europe's labor unions were born out of the failure of their social structure to provide security for their laborers.

The payment and contracting mechanisms of the two countries illustrate, also, the relationship between labor and employer. In India, the laborers were given cash advances for their services. This allowed them freedom from debt. In contrast, workers in England, often, were paid at the end of a term, forcing them into debt for their cash flow requirements.

The nature of contractual agreements also favored Indian workers. For example, weavers could terminate their contracts with merchants by simply returning their advances, whereas the merchant was bound to accept the produced cloth, unable to break the contract. British laborers had no such contractual agreements and, thus, were at the mercy of the employer.

In summary, laborers in India possessed several important advantages over their counterparts in Britain. These included:

1. A means of collective bargaining through jatis
2. Lower levels of unemployment and underemployment made possible by steady demand
3. Superior payment scheme by receiving cash advances
4. Superior rights in contractual agreements
5. A political order characterized by the absence of state interference which is discussed in the next section

4) State Role in Industry:

The role of governance in the two countries is also quite different and revealing. The values of both societies drive the policies of the respective governments.

In India, the state had no coercive powers on the laboring class. The rights of individual laborers were given, upheld, and if necessary revoked by the communities (jatis) themselves. The sovereign states did not establish these rights nor did they interfere in the process of labor-employer dialogue. State intervention was outside the bounds of moral rulership. This put labor in a powerful position within the social-economic order.

In England, however, the government intervened in the labor markets, on behalf of employers. The government was inherently pro-employer in much of its policy-making. For example, when the rare conditions of labor scarcity and increased demand coexisted, the state intervened to establish maximum wages. Even during the worker's rights movements when they attempted to demand higher wages, reduce working hours, and defend basic rights, there was heavy resistance from government-backed well-organized employers.

The British system of governmental control was eventually imposed on Indian society via the East India Company. In the last fifty years of the eighteenth century the power of the Company greatly increased, as did the influence over producers. The laborers' mobility was limited and their earnings curtailed. This led to a steady decline in workers' wages and living conditions, leading to the poverty stereotype of the Indian laborer.

A key characteristic of the Indian social structure was the separation of societal functions. This prevented corruption, through intermixing, in various segments of society, as has happened in Western society. In the modern world of large corporations, the intimate relationship that business has fostered with government (most notably the United States government) is quite apparent as is the corruption in both.

5) Agricultural Production as India's Strategic Advantage:

If Indian labor truly was not subject to exploitation, how could its textile industry be so successful? Interestingly, the answer to this question lies outside of the textile industry itself and actually in India's agriculture.

The first important piece of this puzzle is to understand that wages in this era were not earned entirely in money but were also in the form of grain. In other words, workers received a part of their wages in the form of money and the rest in the form of grain, making the price of grain a key factor in labor costs. Secondly, the retail price of grain in Britain was twice that of the price in India. Weekly grain quantities given as wages were equitable in both countries, while the Indian cost of grain was close to half that in England. Therefore, in terms of money, the cloth production in India was much cheaper, since it required only about half as much cost of grain given to labor. (However, when one combines the absolute value of grain with money wages, Indian workers were making as much, if not more than, the British workers.) Adam Smith explains:

> *"As the money price of food is much lower in India than in Europe, the money price of labour is there lower ... But in countries of equal art and industry, the money price of the greater part of manufactures will be in proportion to the money price of labour...The money price of the greater part of manufactures, therefore, will naturally be much lower in [India] than it is any-where in Europe."* ("*The Wealth of Nations*", Adam Smith, ed. Edwin Cannan, 2 vols. (Chicago, 1976), i, 229 as cited in Parthasarathi, 1998)

The third essential fact that made the Indian system work was the superior agricultural output which led to a greater supply of grain, and, consequently, reduced grain prices. Britain was primarily a wheat-growing country, while India could rely on rice, a more abundant and frequent crop than wheat. The output-to-seed ratio was 20:1 (a conservative estimate) in South India while British agriculture produced a ratio of 8:1. Adam Smith confirms this point[ix]:

> *"In rice countries, which generally yield two, sometimes three crops in the year, each of them more plentiful than any common crop of corn, the abundance of food must be much greater than in any corn country of equal extent ... The precious metals, therefore, would naturally exchange in India ... for a much greater quantity of food than in Europe. The money price...of food, the first of all necessaries, [would be] a great deal lower in the one country than the other."* ("*The Wealth of Nations*", 228-9, as cited in Parthasarathi, 1998)

Besides having rice as a more robust grain, land and labor were also more productive in India. The cultivation techniques and agricultural technology in India were superior. For example, rice was transplanted, saving seed, and reducing wastage of other valuable inputs like water and manure.

The diagram below illustrates the key elements in the Indian textile industry that contributed to its success.

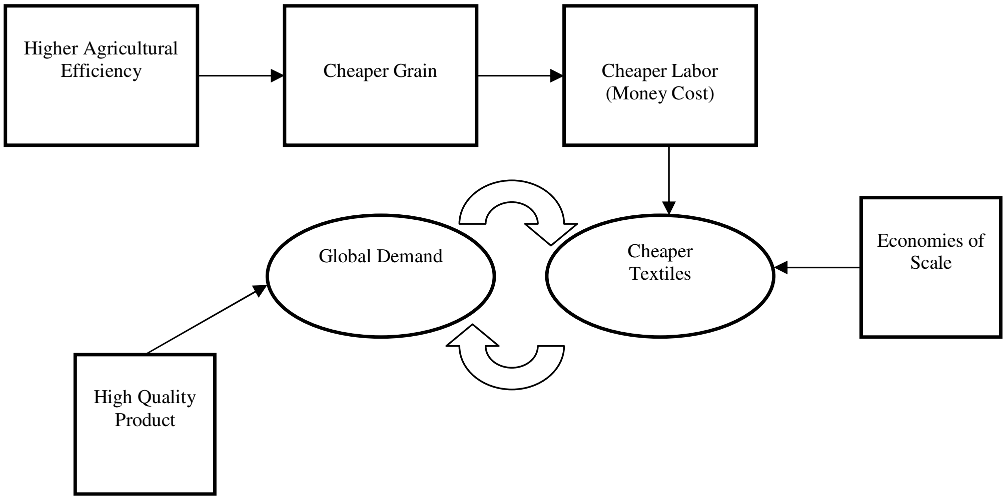

Fig. 1 Summary of Textile Industry

New World Order and the Dismantling of India's Industry:

British colonial rule did not welcome India's competitive industry. The global mercantile enterprise that the British had established linked markets in America, India, China and Africa, with England as the focal hub. America provided cheap cotton and agricultural goods using the free labor of African slaves. This raw material fed the British factories including the weaving mills in Manchester. These textiles were dumped onto a captive Indian population in exchange for cash crops such as indigo and opium (a poppy seed derived narcotic), which, in turn, were dumped in China in exchange for tea. In other words, the British acted as kingpin of an international drug cartel resulting in the Opium Wars and the establishment of the British colony in Hong Kong. British merchants collected the profit for every transaction in this global ring. Britain had great use for India as a producer of raw goods for its own industry, and as a captive market for European finished goods. India, the industrial powerhouse, was a threat to this world order and had to be dismantled. Jeremy Seabrook writes:

> *"Asian economies were manipulated to turn them into producers of raw materials and consumers of European, largely British, goods. The forcing of Bengal farmers to grow indigo to the neglect of their own crops, with the result that many starved...the compulsory cultivation of opium... "smuggled" to China and profits "found their way" into coffers of the Company. Indian farmers were compelled to grow opium for the imperial government to pay for the tea it imported from China.* ("Independence and illusion of equality," by Jeremy Seabrook. The Statesman, Kolkata, July 7, 2002.)

Below are some facts and figures that clearly illustrate the complete decimation of Indian industry and the subsequent enslavement of its markets and its people:

> *By 1846 the tables were completely turned. India did not export any cotton goods at all, but had to import from England 214 million yards of cloth as compared with 5 million in 1835 and 8 lakhs yards in 1814. In 1938-39 [Indian] export trade was 45 per cent raw materials; 23 per cent foodstuffs, and 30 per cent semi-manufactured and manufactured articles. Import trade in the same year had grown to about 70 per cent manufactures, mostly finished consumption goods. India has had to maintain a continual favourable balance of trade by exporting raw materials to meet the invisible items of imports, home charges, debt, services, and payments, etc. Our exports being mostly raw materials and other primary products, balances of trade have been invariably against us*. ("The Ruin That Britain Wrought", K.M. Munshi Pg 8)

The annexation of Bengal into the East Indian Company, after the defeat of the Nawab, and the subsequent colonial policies is a telling episode that reflects British rule as a whole. The draconian increase in land taxes and the brutality of the Company led to the Plunder of Bengal, reducing the state to shambles. It is estimated that the famine of 1769-70 claimed the lives of one-third of the region's total population.[x] This famine was the result of the Imperial edict that made cash cropping of indigo and poppy compulsory, forcing farmers to neglect their own crops. Meanwhile, Company employees fattened their wallets on plundered wealth.

> **…** *between the battle of Plassey in 1757 and the Battle of Waterloo in 1815 about 1000 million pounds were transferred from Indian hoards to English banks. After the Battle of Plassey "the shower of wealth fell copiously on the company and its servants. A sum of 800 thousand pounds sterling, in coined silver, was sent down to Fort William. Trade revival and the signs of affluence appeared in every English house." Capital accumulation and Industrial Revolution in England followed capital depletion and industrial devolution in India."* ("The Ruin That Britain Wrought" K.M. Munshi pg 4-5)

In the shift of roles from "India as an industrial competitor" to "India as an agricultural cash cow," the British destroyed the textile industry. Governor-General William Bentinck described the destruction of India's weaving industry as *"a misery without parallel in the history of Commerce"*.[xi] The textile industry was not the only victim in this onslaught; others include India's iron, steel, shipbuilding, and agriculture industries, which were either radically destroyed or fundamentally handicapped. This systematically destroyed India's once flourishing industrial sector, which had given it not only global power in commerce, but also the security of self-reliance.

The peak of British influence coincided with the obliteration of Indian industry. In 1841, Labouchere, British Chancellor of the Exchequer, stated *"The British have utterly destroyed the manufactures of India by their manufactures. The district of Dacca, the Manchester of India, has dwindled into insignificance"*[xii].

Colonial greed superseded the "liberalism" that sections of European society had proclaimed. This reached its ugliest manifestation in the large-scale holocausts of India's population that resulted from British policies to maximize their self interests. The book, *"Late Victorian Holocausts,"* by Mike Davis, is perhaps the most vivid and well-documented account of the human toll of the British economic and social policy in India. Details of the famines that afflicted India between 1876 through the early 1900s and the

devastation they caused on the populace are described in terms of British control of markets, means of production, taxation, and military might. Using pictures and testimonies, the book vividly recounts the scene in India during these famines. It asserts that British policymakers made willful and conscious decisions that led millions to starve to death. Davis cites British sources that estimate that during 1876-1902, 12.2-29.3 million Indians died as a result of the famines[xiii]. Davis poses the question,

> *"…how do we explain the fact that in the very half-century when peacetime famine permanently disappeared from Western Europe, it increased so devastatingly throughout much of the colonial world? Equally, how do we weigh smug claims about the life-saving benefits of steam transportation and modern grain markets when so many millions, especially in British India, died alongside railroad tracks or on the steps of grain depots?"* ("Late Victorian Holocausts", Mike Davis, pg 9)

The famines and the colonial culpability behind them show that British rule forever transformed the Indian socioeconomic landscape in fundamental and profound ways. The famines completely decimated whole generations of people and the traditions that these people had kept alive. A bulk of the population literally starved to the bone, creating a wealth gap between a small population of elites and the common man who became poor. As Davis aptly comments:

> *By the end of Victoria's reign… the inequality of nations was as profound as the inequality of classes. Humanity had been irrevocably divided. And the famed "prisoners of starvation,"… were as much modern inventions of the late Victorian world as electric lights, Maxim guns, and "scientific" racism.* ("Late Victorian Holocausts", Mike Davis pg. 16)

The dismantling of Indian industry to pave the way for this new world order was accompanied by disrupting the indigenous socio-political order and replacing it with chaos. The British were free to re-engineer a new socio-political order to serve the purposes of their rule. In the late 19th century they began the famous social restructuring, based on the census of jatis, to produce what has survived as the caste system and falsely blamed on Hinduism.

According to Professor Prasannan Parthasarathi, contrary to the widely held revisionist interpretation that British rule was rooted in indigenous forms of governance, there was a dramatic break between indigenous and British notions of justice and moral rulership. In reality, the colonial state implemented European-style policies to discipline and fix labor. The workers rights that Indian laborers once enjoyed were exchanged for new rights, such as democracy and civil liberties - the basis of the power-struggle of the European labor movements. However, these rights have done little to improve the state of Indian laborers in modern post-colonial India, which retained colonial labor policies. This reflects the discontinuity in pre-colonial and colonial social, governmental, and economic structures. To illustrate this point we should consider the fact that <u>the real earning of male agricultural laborers in South Asia in 1976 was, in fact, a third of the level in the late-eighteenth-century</u>. Women bore the largest burden of these decreased wages thereby increasing their dependence on men.

Edward Said's critiques of Eurocentrism focus on European agendas to control land. However, it needs to be pointed out that Said's analysis largely used colonial practice in

the largely un-industrialized Arab region - in India's case, as is evident by this case study, colonial concerns were heavily centered on labor and industry. The central agenda of colonialism was to attack Indian society in order to subjugate it, and then superimpose blame for the resulting poverty on an inherent Indian inferiority.

Conclusion:

The British textile industry was one of the first and more successful industries attributed to the genius of the European Industrial Revolution. Actually, however, it was the British who were struggling to compete with India in this manufacturing sector. By trying, desperately, to imitate the quality and price of Indian cloth, the British were forced to industrialize.

> *The cotton revolution, first in England, but very soon all over Europe, began by imitating Indian industry, went on to take revenge by catching up with it, and finally outstripped it. The aim was to produce fabrics of comparable quality at cheaper prices. The only way to do so was to introduce machines -- which alone could effectively compete with Indian textile workers. ("Civilization and Capitalism", Fernand Braudel, trans. Sian Reynolds, 3 vols., New York, 1985, iii, 572. As cited in Parthasarathi, 1998.)*

(An interesting and largely unknown fact is that the British not only imitated India's industry, but were so captivated by Indian aristocratic lifestyles that they tried to adopt these as a mark of sophistication. The grandeur and pomp of the Mughal court greatly impressed many senior employees of the East India Company. They attempted to imitate it by wearing Indian clothing, having Indian concubines, and even projecting themselves as patrons of Indian arts and crafts. All this mimicry is well documented in a recent book, "*White Mughals*" by William Dalrymple.[xiv])

The European Industrial Revolution was thus a reaction to their relative backwardness in industry and agriculture. The 'discovery' and subsequent exploitation of America by means of African slave labor was a major input in Europe's journey to world hegemony. The relations among these multiple factors are complex as explained below:

> *…Europe did not pull itself up by its own economic bootstraps, and certainly not thanks to any kind of European "exceptionalism" of rationality, institutions, entrepreneurship, technology, geniality, in a word – of race. We will see that Europe also did not do so primarily through its participation and use of the Atlantic economy per se, not even through the direct exploitation of its American and Caribbean colonies and its African slave trade… instead Europe used its American money to muscle in on and benefit from Asian production, markets, trade – in a word, to profit from the predominant position of Asia in the world economy…Europe climbed up on the back of Asia, then stood on Asian shoulders – temporarily.*
> ("Reorient*: Global Economy in the Asian Age*", Andre Gunder Frank pg 4-5)

The thorough dismantling and incapacitation of whole industries in Asia were designed to ensure the colonies' dependency on the Europeans. The intellectual slavery that accompanied colonial rule was just as essential, and is sustained till today in India.

One must concede that the British would have invented their mechanized weaving industry eventually. However, it is apparent that India was ingenious in its industrial technologies and its social structure, and would have assimilated these faster in the

absence of colonialism. Furthermore, without the wealth that was pillaged from the colonies, Europe would have continued lagging behind.

As Brook Adams rightly remarks "In themselves inventions are passive, many of the most important having lain dormant for centuries waiting for a sufficient store of force to have accumulated to set them working. ...Before the influx of the Indian treasure and the expansion of credit which followed, no force sufficient for this existed." ("*The Ruin That Britain Wrought*", K.M. Munshi pg 4-5)

The mills of England would never have succeeded had it not been for the unfair trade practices that the British imposed, such as heavy duty on Indian cloth in Britain and the dumping of British cloth in India completely free of duty. This was unilateral trade protectionism in practice.

"had not such prohibitory duties and decrees existed, the mills of Paesley and Manchester would have stopped in their outset and could hardly have been again set in motion, even by the power of steam. They were created by the sacrifice of Indian manufactures... ("*The Ruin That Britain Wrought*" K.M. Munshi pg 8)

The colonial relationship between the East India Company and India parallels today's great drama of globalization, with its relationship between the South and their "advanced" industrial partners. Therefore, a re-examination of the economic and technological history of India is urgently required. Powerful Asian economies have emerged and are, once again, exporting sophisticated manufactured goods to the rest of the world. Conventional Eurocentric wisdom on the superiority of Western culture in matters of material progress must be rejected.

Section B

Krishi- Parashara: An Early Sanskrit Text on Agriculture

By Manikant Shah and D.P. Agrawal

"Krishi Parashar" is an exposition of the ancient Sanskrit text dealing with meteorology and general agriculture. It is translated by Sadhale with commentaries by H V Balakundi and Y L Nene. The Introduction focuses on agriculture in Vedic Arya life.

> 'The knowledge and techniques of farming have always been a part and parcel of the Indi"n civilization. That the culture and civilization of the Vedic Aryas were based and centered on agriculture is fully borne out even by the oldest portions of the Vedas. The importance of Indra, the rain god, and the large number of prayers addressed to him in the RigVeda prove beyond doubt that the Vedic Aryas were agriculturists'.

The authors use literary records to trace the evolution of agricultural science as far back as Kautilya's *Arthasastra* (c. 400 BC) with its details on agriculture. The question of the identity of Parashara, the author of Krishi Parashara, is discussed in detail. In the ancient texts, the name "Parashara" appears as an individual and as an institution at different times, and in relation to different sciences such as astronomy, astrology, medicine, agriculture, social rules, code, and so on. Singh (1971) suggests two additional factors in considering an author's identity:

> '(i) Parashara also is a gotranama; i.e., a family name, it can be shared by several individuals belonging to the Parashara clan; and (ii) in ancient India the followers of a certain school of thought used the same name which was usually the name of the founder of that school.' Singh (1971)

Singh has hinted that the present Krishi- Parashara might be an abridged revision of the original work of Parashara.

The difficulty in dating the Krishi Parashara text is also discussed.

> 'The problem of fixing the date of the work is directly and necessarily linked with that of the author's identity and can, at best, be answered only by venturing a conjecture vacillating between centuries. Majumdar maintains that the author of Krishi-Parashara was perhaps earlier than the 6th century CE but certainly not later than the 11th century CE. Excluding the Parasharas associated with the Vedas, Mahabharata, and Artha-sastra on account of their antiquity, Varahamihira's references to Parashara as an authority on agriculture, astronomy, astrology, and meteorology become the starting point for fixing the date of the author of Krishi-Parashara. Kane and other scholars of Dharmasastra fix the date of Parashara Smriti between 1st and 5th century CE. If

> this Parashara is identified with the author of Krishi-Parashara [according to Singh (1971)], this conjecture that the 4th century is the lower limit is further strengthened'.

Y L Nene's commentary to the text maintains that Parashara must have written the manuscript prior to Arthasastra of Kautilya that is prior to 4th century BC.

The ancient texts are usually written in verse and meter (Chhanda), following Sanskrit grammar rules. The Krishi-Parashara text consists of 243 verses mainly in the popular anustubh meter. Meters in the Sanskrit language are differentiated by their number of syllables. The anusthubh meter has eight syllables in each line (pada) in a verse that has four lines (padas), yielding a total of 32 syllables in the entire verse.

The audience for the text is farmers, so the theory of agriculture is expounded in a style that farmers could appreciate and implement in their profession. The text is essentially a farmer's almanac containing astronomical and meteorological data arranged according to the seasons and months in ancient India. It is the farmer's ready reference containing basic data on geographical and climatic conditions, helpful in planning and managing farming spread over several months.

This treatise includes meteorological observations relating to agriculture, management of agriculture, management of cattle, agricultural tools and implements, seed collection and preservation, plowing, and all the agricultural stages from preparing fields to harvesting and storing crops. The religious aspect of Indian culture is present because the text begins with salutations to Prajapati, the Lord of the living, and ends with the prayer to the Laxmi, the goddess of wealth and prosperity.

Commenting on the meteorological aspects, H V Balakundi says,

> "Sage Parashara shows a remarkable quest of agricultural activities since he knows from his personal experience the intimate and close relationship between agriculture and rainfall. It would be pertinent to note here that the sage makes full use of his astrological knowledge for predicting the availability of rainwater during the different stages of crop growth. Thus he enables us to study his concepts of clouds and rainfall'. This leads Balakundi to expose in some detail the relationship between the meteorological aspects and the astrological predictions considered by Parashara in his work. Parashara has in a major way linked the consistent meteorological conditions for agriculture to the planets and their positions. However, he points out 'a critical study of this ancient text is impaired because the technique for determining the ruling planet of the year is not clear."

After this the sage turns his attention to the visible causes of rainfall – the clouds. He lists four types of clouds - the Aavarta, Samvarta, Pushkara, and Drona. These four types differ according to the type of rain they cause. Though Parashara has outlined techniques

for measuring rainfull in relation to cloud type, Balakundi finds them impractical to follow. In Balakundi's view, they are imprecise and unwieldy and may have neither satisfied the agricultural community of that era nor the scholars of this branch of astrology. Balakundi guesses that the search for a better technique might have led to an evolved version found in Kautilya's Arthshastra of the 4th century BCE . Here the rainfall is measured in terms of Drona instead of Yojanas.

Balakundi makes the interesting observation that the sage, Parashara, advises the farmers to measure the monthly rainfall starting with Paush (which is in the middle of the month of March). Parashara stresses that in order to know the quantity of monthly rainfall the observer has to daily track the wind direction, by fixing a rod with a flag attached to it. According to Parashara, wind from the North or the West brings rain and wind from the East or the South indicates absence of rain.

Y L Nene notes that in verses 1 to 10, Parashara highlights the importance of good management in farming, using examples relevant to his time (verses 79 to 83), with strong suppport in verses 79, 82 and 83. This information is as relevant today as they were more than 2000 years ago.

Nene says that since sustainable agriculture requires good management the message of Parashara will hold true as long as agriculture exists. Nene then structures the text under sub-headings like: management of cattle, manure, the plow and other implements, the plowing, seed collection and storage, sowing and planting, water retention, weeding, draining of water, plant protection, water harvesting, reed fixing ceremony, token harvest, threshing pillar, the pushyayatra festival, harvesting and measuring yield, and the storage of grains, observations and suggestions which cover the entire operation, process and procedure of good agriculture.

In his concluding remarks, Nene emphasizes that Krishi-Parashara is unquestionably one of the oldest texts on Indian agriculture, with a a clear emphasis on the paddy (rice) cultivation. Throughout the text, there is evidence of the influence of the astrology of the times. Superstitions existed along side sound knowledge of agriculture.

Nene avers that the text gives the impression of being incomplete. He attributes this to Parashara's emphasis on rice cultiviation. He says Parashara describes prediction of rainfall, cattle management, construction of a plow and other implements, making furrows for sowing, and time of sowing different crops. However, when it comes to details for successfully growing a crop, Parashara concentrates mainly on rice. Nene believes that the original Krishi Parashara might have been a larger text with the present version being one edited to suit the needs of eastern India where rice was and still is the predominant crop.

Medicinal Properties of Neem: New Findings

By D.P. Agrawal

The Indian tradition has recognized the beneficial properties of Neem for thousands of years. It is commonly said that, “Each part of the neem tree has some medicinal property.” Biswas et al (2002) have recently reviewed the biological activities of some of the neem compounds, pharmacological actions of the neem extracts, and clinical studies and plausible medicinal applications of neem. This included a safety evaluation of the Neem.

Neem has two closely related species: one is popularly known as the Indian Neem (Margosa tree) or Indian Lilac, and the other is known as Persian Lilac. Neem is extensively used in ayurveda and its Sanskrit name is Arishtha, meaning 'reliever of sickness.' The tree is still regarded as a 'village pharmacy' in India. The importance of the neem tree has been recognized by the US National Academy of Sciences, which published a report in 1992 entitled 'Neem a tree for solving global problems.'

More than 135 compounds have been isolated from different parts of neem and several reviews have been published on the chemistry and structural diversity of these compounds. The compounds have been divided into two major classes: (i) isoprenoids, such as diterpenoids and triterpenoids containing protomeliacins, limonoids, azadirone and its derivatives, gedunin and its derivatives, vilasinin type of compounds and C-secomeliacins such as nimbin, salanin and azadirachtin; and (ii) non-isoprenoids, which are proteins (amino acids) and carbohydrates (polysaccharides), sulphurous compounds, polyphenolics such as flavonoids and their glycosides, dihydrochalcone, coumarin and tannins, and aliphatic compounds.

Biological Properties of some Neem Compounds

Nimbidin, a major crude bitter principle extracted from the oil of seed kernels of Indian Neem, has demonstrated several biological activities. From this crude principle some tetranortriterpenes, including nimbin, nimbinin, nimbidinin, nimbolide and nimbidic acid have been isolated.

Medicinal Uses

Various parts of the Neem tree have been used as traditional Ayurvedic medicine in India. Besides being a general health promoter, neem oil, the bark and the leaf extracts have been therapeutically used to control leprosy, intestinal helminthiasis, respiratory disorders and constipation. Neem is also used to treat rheumatism, chronic syphilitic sores and indolent ulcers. Neem oil is also used to control various skin infections. Neem’s bark, leaf, root, flower and fruit together cure blood morbidity, biliary afflictions, itching, skin ulcers, burning sensations and pthysis (see Table 1).

<u>Immunostimulant activity:</u> The aqueous extract of the neem bark and leaf also possesses anticomplement and immunostimulant activity. Neem oil has been shown to possess activity by selectively activating the cell-mediated immune mechanisms to elicit an enhanced response to subsequent mitogenic or antigenic challenge.

<u>Hypoglycaemic activity:</u> The aqueous extract of neem leaves decreases blood sugar levels significantly and prevents adrenaline and glucose-induced hyperglycaemia. Recently, a hypoglycaemic effect was observed with leaf extract and seed oil, in normal as well as alloxan-induced diabetic rabbits.

<u>Antiulcer effect:</u> The aqueous extracts of the neem leaf and bark produce highly potent antiacid secretory and antiulcer activity.

<u>Antifertility effect:</u> The intra-vaginal application of neem oil, prior to coitus, can prevent pregnancy. It could be a novel method of contraception. NIM-76, a refined product from neem oil, was studied to determine whether intra-vaginal application would prevent pregnancy without an adverse effect. The data suggested that it is safe.

<u>Antimalarial activity:</u> The neem seed and leaf extracts are effective against both choroquin-resistant and sensitive strain malarial parasites.

<u>Antifungal activity:</u> Extracts of neem leaf and neem oil seed kernels are effective against certain fungi including: Trichophyton, Epidermophyton, Microspor Trichosporon, Geotricum and Candida.

<u>Antibacterial activity:</u> Oil from the leaves, seed, and bark of the neem possesses a wide spectrum of antibacterial action against Gram-negative and Gram-positive microorganisms, including M. tuberculosis and streptomycin resistant strains. In vitro, it inhibits Vibrio cholerae Klebsiella pneumoniae, M. tuberculosis and M. pyogenes. Antimicrobial effects of neem extract have been demonstrated against Streptococcus mutans and S. faecalis.

<u>Antiviral activity:</u> The aqueous leaf extract offers antiviral activity against vaccinia virus, chikungemya, and measles virus.

<u>Anticancer activity:</u> The neem leaf aqueous extract effectively suppresses oral squamous cell carcinoma induced by 7, 12-dimethylbenz[a] anthracene (DMBA), as revealed by reduced incidence of neoplasm. Neem may exert its chemopreventive effect in the oral mucosa by modulation of glutathione and its metabolizing enzymes.

<u>Antioxidant activity:</u> The antioxidant activity of neem seed extract has been demonstrated in vivo during horse-grain germination.

<u>Effect on central nervous system:</u> Varying degrees of central nervous system (CNS) depressant activity in mice were observed with the leaf extract. Fractions of acetone extract of the leaf showed significant CNS depressant activity.

<u>Neem extract:</u> It is effective in curing ringworm, eczema and scabies. Lotion derived from neem leaf, when locally applied, can cure these dermatological diseases within 3-4

days in acute stage or in a fortnight in a chronic case. A paste prepared with neem and turmeric was found to be effective in the treatment of scabies in nearly 814 people.

From time immemorial, Indian ayurvedic practitioners have prescribed the oral use of the neem leaf extract for treating malaria. Recently, a clinical trial was conducted to test the efficacy of the neem extract in controlling hyperlipidemia in a group of malarial patients severely infected with P. falciparum. The lipid level, especially cholesterol, was found to be lower during therapy when compared to non-malaria patients. Reports are available regarding the use of neem to treat patients suffering from various forms of cancer. One patient with parotid tumor and another with epidermoid carcinoma responded successfully when treated with neem seed oil.

Conclusion

This traditional Indian plant medicine has now led to several internationally acclaimed, industrially useful, and therapeutic preparations and compounds. This has encouraged scientists to explore this medicinal plant. The development of modern drugs from neem should be emphasized in disease control, keeping in mind the global trend in using nontoxic plant products having traditional medicinal use. Indeed, the time has come to capitalize on this centuries-old knowledge of neem, using modern approaches of drug development.

INDRANI STOPPED EDITING HERE ON NOV 8

Turmeric: Uses, Chemistry and Intellectual Property Rights

By Lalit Tiwari and D.P. Agrawal

Turmeric is the most important medicinal plant in the Indian traditional medicine system. Almost every cooking recipe in India has a little bit of turmeric. In addition to adding taste, Indians have known its multiple benefits for millennia, and some persons recently tried to patent these old cures. Turmeric powder significantly increases the mucus content in gastric juices, and Indian cuisine lays emphasis on turmeric's therapeutic effect against gastric disorders. Curcuma oil, curcumin and its alkali salts prevent histamine induced gastric ulceration.

India is the world's principal supplier of turmeric, which is extensively cultivated all over the country. In India, the total acreage under turmeric has been estimated from 60,000 to 100,000 acres, with a production of approximately100,000 tons of rhizomes per annum.

In India, the popular name for the turmeric plant is haldi. The turmeric rhizome is very aromatic, with a musky odour and yellow colour. The plant is a robust perennial with a short stem and tufted leaves. The pale-yellow flowers are found in dense spikes, topped by a tuft of pinkish bracts. The rhizomes, which yield the colorful condiment, are short and thick with blunt tubers.

Uses of Haldi

In traditional Indian medicine, turmeric is known as a stomach cleanser and blood purifier, and is useful in treating: the common cold, leprosy, intermittent fevers, affections of the liver, dropsy, purulent ophthalmia (inflammation of the eye), otorrhea (discharge from ear), indolent ulcer, pyogenic (forming pus) affections, wound healing and inflammation. The rhizome of turmeric is highly aromatic and antiseptic. Its paste is used in cleansing and disinfecting the skin and skin ulcer without drying out its natural oil.

Clinical tests have proved the bactericidal properties of turmeric. Curcumin and other curcuminoids inhibit growth of various bacteria like S. aureus, S. paratyphi, Trichophyton gypseum and Mycobacterium tuberculosis in concentrations varying from 1 in 20,000 to 1 in 640,000. The essential oils show marked anti-microbial activity against gram negative (Vibrio cholerae, Salmonella typhi, Klebsiella aerogenes, B. coli) and gram-positive organisms (Corynebacterium diphtheriae, ß-hemolytic streptococci). The essential oil fractions from C. longa rhizomes of various habitats exhibit fungistatic (inhibiting the growth of a fungus) activity particularly against Aspergillus niger and Physalospora tucumanesis, Ceratocystis paradoxa, Sclerotium solfsii, curvularia lunata, Helminthosporium sacchari, Fusarium moniliforme and cephalosporium sacchari.

In the Himalayan region, turmeric or haldi is commonly used for contraception, swelling, insect stings, wounds, whooping cough, inflammation, internal injuries, pimples, injuries, and as a skin tonic.

In Ayurveda and Siddha Medicine, it is used for preparations such as katu tikta rasam, veeryam, ruksham, varnyam, and in prameham, pandu, rakta-dosham, krimi, vranam, and pinasam. The conditions treated include asthma, dysmenorrhoea (painful menstruation), psoriasis (an inflammatory skin disease), eczema, arthritis, hepatic and digestive disorders, and prevention and treatment of cardiovascular diseases.

In Unani medicine, turmeric or haldi is used to alleviate liver obstruction, dropsy, and jaundice. It is used externally against ulcers and inflammation.

The general public in India use haldi or turmeric internally and externally in the following ways:

Internally

- Sweetened milk boiled with turmeric is a popular remedy for cold.
- Turmeric is given in liver ailments and in jaundice.
- Juice of fresh rhizome is used as an anthelmintic (eliminating parasitic worms).
- Root is usefully administered in intermittent fevers.
- It is given for flatulence, dyspepsia and weak stomach.
- It is used both externally and internally in skin diseases due to impurity of the blood.
- Turmeric is also given internally with cow's urine in prurigo (itching papules) and eczema. Its powder is sprinkled on ulcers to stimulate them to healthy action.
- Ghee mixed with powdered turmeric is given to relieve cough.
- A paste of turmeric alone or combined with the pulp of Neem leaves is used in ringworm, obstinate itching, eczema and other parasitic skin diseases.

Externally

- Juice of the fresh rhizome is applied to fresh wounds, bruises and leech-bites.
- A paste of turmeric and the leaves of Justicia adhatoda with cow's urine are rubbed on the skin in prurigo.
- Mixed with gingelly oil it is applied to the body to prevent skin eruptions.
- Turmeric paste mixed with a little lime and saltpetre and applied hot is a popular application to sprains, bruises, wounds, and inflammatory troubles of the joints.
- In small-pox and chickenpox a coating of turmeric powder or thin paste is applied to facilitate the process of scabbing, and a turmeric decoction (1 part of the bruised root to 20 parts of water) is applied as a lotion to relieve the burning in catarrhal and purulent opthalmia popularly known as "country sore eye", and conjunctivitis.
- A piece of rag soaked in it, and kept constantly over the affected eye relieves the burning and moderates the urgency of the symptoms.
- For painful and protruding piles an ointment made of turmeric, hemp leaves, onions, and warm mustard or linseed oil gives great relief; also effective in eczema, itches, etc.

- In pemphigus (blisters on the skin and mucous membranes) and shingles, the part to be treated is first smeared with a thick coating of mustard oil and then dusted and with turmeric powder is cured within 3 or 4 days.
- In catarrh and coryza (inflammation of nasal mucous membrane) the inhalation of the fumes of the burning turmeric through the nostrils causes a copious mucous discharge and gives instant relief; the fumes are also used to relieve hysterical fits.
- Turmeric and alum powder in the proportion of 1 to 20 is blown into the ear in chronic otorrhoea. With borax as a paste it is applied to reduce indolent swellings.

Other uses of Haldi
Dried rhizomes are largely used as spices and it is also used in making Indian pickles and curry powders.

It is one of the most important colouring materials in India. The rhizomes yield the orange-red dye. It is much used to impart a yellow colour to cloth. In the Himalayan region dried roots are used in many religious practices and its powder is used as pithiya (for tilaka – a religious mark on the forehead).

Turmeric colour also serves as a chemical indicator since its colour changes when acids or alkalies are added to it.

Curcuma oil (obtained from haldi) is an effective mosquito repellant and compares favorably with dimethyl phthalate in its repellant action against mosquitoes.

Chemistry of Haldi
According to N. M. Khanna (1990) turmeric's major constituents are: 'curcumin', various 'curcuminoids' and 'curcuma oil' (particularly dl-ar-turmerone). Turmeric exhibits a wide range of biological activities, e.g. anti-bacterial, anti-inflammatory, hypolipidemic, hepatoprotective, lipoxygenase, cycloxygenase, protease inhibitory effects. In addition, it is an effective active oxygen species scavengers and lipid peroxidase (a class of oxidoreductase enzymes) inhibitor. Curcumin and the curcuminoids also lower cholesterol, reduce platelet aggregation, inhibit proliferation of cancer cells and improve digestion by increasing the flow of bile from the gallbladder.

Curcumin and the essential oils of C. longa, particularly sodium curcuminate, differentially affect the individual constituents of bile.

Extracts of C. longa rhizomes exhibit good preventive activity against carbon tetrachloride induced liver injury *in vivo* and *in vitro*.

Curcumin inhibits intestinal gas formation by Clostridium perfringens at 0.05% concentration. Its effect was evaluated at 0.005, 0.013, 0.025 and 0.05% on gas formation by C. perfringen of intestinal origin. Gas formation decreased gradually as the curcumin concentration increased and there was no gas when curcumin concentration was 0.05%, the level at which bacterial growth was inhibited completely.

Oral administration of curcumin and curcuminoids (750 mg/kg) has been reported to prevent the formation and dissolution of urinary calculi.

Turmeric powder, extracts and curcumin also exhibit antioxidant property.

Conclusion

India is considered one of the world's 12 megadiversity countries. Its traditions harnessed this diversity to develop medical systems offering strong and safe treatments for many diseases. Use of turmeric is very old in Ayurveda. Its ubiquitous use as a spice shows that ancient Indians knew that daily use of turmeric is very effective against many diseases. Today India is facing a great problem, particularly relating to intellectual property rights, of its traditional knowledge.

Shilajit, the Traditional Panacea

By Lalit Tiwari & D.P. Agrawal

Shilajit is an important drug in the Ayurvedic and folk-medicine systems of India. In the raw form it is a bituminous substance, which is a compact mass of vegetable organic matter composed of a dark red gummy matrix. It is bitter in taste. The botanical name of Shilajit is Asphaltum (mineral pitch).

In the Ayurvedic texts it is called *silajatu* or s*hilajatu*, but is commonly known as Shi*lajit*. Its Sanskrit meaning is "conqueror of mountains and destroyer of weakness." Several other terms like *dhaturas, dhatusara, shiladhatu*, etc. also describe it in ancient medical texts like Sushruta Samhita, Charak Samhita, Rasarangini, etc. The term *dhau*, when used synonymously for *Shilajit* (like dhahurasa, dhahusara etc.) simply emphasized its potentialities as rarayana, which increases the activities of the saptadhatus of the body.

Shilajit is usually collected from the topsoil or from between rock crevices, and in a hot summer climate. In India, it is found in the romantic surroundings of the Himalayas- from Arunachal Pradesh in the East to Kashmir in the West. It is also found in Afghanistan, Bhutan, China, Nepal, Pakistan, Tibet, and Norway, where it is collected in small quantities from steep rock faces at altitudes between 1000 and 5000 m. *Shilajit* samples from different region of the world have different physiological properties.

Shilajit in Ayurveda

In the Charak Samhita, *Shilajit* is described as a product of four minerals: gold, silver, copper and iron, whereas Susruta Samhita included two more minerals, lead and zinc, in its composition. It is classified into four categories, according to the predominant mineral in the source rock: Sauvarna, Rajat, Tamra and Lauha. The last variety *Lauha shilajit* or *blackish-brown Shilajit* is common and supposedly the most effective. Charaka Samhita mentions that without the aid of *Shilajit* no curable disease can be alleviated.

According to Susruta Samhita 15, 32-40, obesity can be cured by taking enemas of drugs with liquefying properties which contain minerals like Silajatu, cow's urine, the three myrobalans, honey, barley etc. Traditionally people use it with pure milk to enhance energy, sexual and spiritual power.

Origin of Shilajit

Many researchers claim that *Shilajit* exuding from the rocks of mountains is basically derived from vegetative source. Several shlokas of Susruta Samhita and Rasarangini also maintain this view. According to Sushruta, in the months of May through June the sap or juice of plants comes out as gummy exudation from the rocks of mountains due to the

strong heat of the sun. Rasarangini and Dwarishtarang also claim that *Shilajit* is an exudation of latex gum-resin etc. from plants found in the crevices of mountain rocks and in a climate of scorching heat. But the exact source of the origin of *Shilajit* is still a controversy.

There are several hypotheses regarding the origin of Shilajit.

- Early work on Sh*ilajit* shows that it is mainly composed of humus (the characteristic constituent of soils) together with other organic components.
- Some workers think that Euphorbia royleana Boiss plants are responsible for the origin of *Shilajit*, because these plants are very rich in latex.
- The chemical analysis of Shilajit by researchers at Benaras Hindu University in India indicate humification of some resin/latex bearing plants to be the most likely source of *Shilajit*.
- Recent discoveries suggest that the humification of resin-bearing plants led to the major organic mass of *Shilajit*. Chemical analysis shows that about 80 percent of humus components are present in *Shilajit*.
- Another recent research claims that mosses such as species of Barbula, Fissidenc, Minium, Thuidium and species of Liverworts like Asterella, Dumortiera, Marchantia, Pellia, Plagiochasma and Stephenrencella-Anthoceros are present in the vicinity of *Shilaji*t exuding rocks; and that these bryophytes are responsible for forming *Shilajit*. The bryophytes show in their tissues, minerals and metals such as copper, silver, zinc, iron, lead etc, which are similar to the elements present in *Shilajit*.
- The composition of *Shilajit* is influenced by factors such as plant-species, the geological nature of the rock, local temperature profiles, humidity and altitude.

Shilajit and Health

Shilajit is a very important drug for many diseases. It was used as a drug in prehistoric India. There is evidence of *Shilajit (Silajatu)* in the Indus civilization. Traditionally it is used as a tonic to increase power. The following health properties are found in *Shilajit*:

- Helps accelerate processes of protein and nucleic acid metabolism and stimulates energy providing reactions.
- Counteracts Diabetes and regulates the blood sugar level.
- Purifies blood, improves functioning of pancreas and strengthens digestion.
- Reduces fat, dissolves tumours, and counteracts thirst.
- Promotes the movement of minerals, especially calcium, phosphorous, and magnesium into muscle tissue and bone.
- Stimulates the immune system and improves restoration (recovery) after exercise.
- Increases levels of growth hormone in diabetic patients and is a potent anti-ulcer agent.

Conclusion

Shilajit is a humus rich blackish-brown substance, which is very useful in many diseases and serves as a potent tonic. But its origins are still being debated. According to

conventional wisdom it increases virility, cures diabetes, and is useful in various Ayurvedic medicines.

Safed Musli: A Potent Traditional Medicine and Rural Economic Goldmine

By D. P. Agrawal

Safed Musli grows wild in thick forests and is a traditional medicinal plant. Its tuberous roots are used mainly in Ayurvedic medicines, for example, in the nutritive tonic used for curing general sexual weakness. *Safed Musli* has been named in the Atharva Veda as one of the divine herbs used for curing many health related problems. The origin of this wild herb can be traced back to the Aravallis, the oldest mountain ranges of the Indian sub-continent, from where it spread to the nearby areas, presently known as the states of Gujarat, Rajasthan and Madhya Pradesh. It is an herb with sub-erect lanceolate leaves. Nowadays, its global demand, especially in the Middle East, Europe, Japan and the USA, has made this wild herb very costly.

Uses

It would not be an exaggeration to call *Safed Musli* a unique, potent and versatile medicine discovered by the genius of ancient India. It is a rich source of over 25 alkaloids, vitamins, proteins, carbohydrates, steroids, saponins, potassium, calcium, magnesium, phenol, resins, polysaccharides etc. *Safed Musli* is an important ingredient in over 100 Ayurvedic, Allopathic, Homeopathic and Unani medicinal preparations. As a protein rich food supplement, there is a rapidly growing international demand for processed *Safed Musli*.

The following are some of its main uses in medicine:

- General sex tonic, aphrodisiac and revitalizer
- Remedy for Diabetes.
- Cure for Arthritis.
- Cure for Natal and Post-Natal problems.
- For reducing Rheumatism and Joint Pains.
- For increasing lactation in feeding mothers and lactating cows.
- Remedy for Diarrhea and Dysentery
- Remedy for Gonorrhea
- Used for Leucorrhoea
- Used as a diuretic
- Miscellaneous other applications in Ayurvedic and Pharmaceutical Industries.

Cultivation and Income

If the exploitation of the natural sources of *musli* continues at its present rate, this herb will become extinct within a few decades. It is therefore imperative to grow it systematically. During the last decade, some efforts were made to popularise the cultivation of *musli*, because it is, by far, the most profitable traditional crop. It is indigenous to most parts of central India where the climate is conducive to its growth. It has now been found that *musli* can grow successfully within a wide range of temperature and rainfall conditions.

An average crop yields 20-30 quintals of *wet musli* per acre. After peeling and drying, only 20 percent (4-4.5 quintals) of *dried musli* is finally harvested. In the indigenous market, the present rate of *dried musl*i ranges from Rs 800 to Rs 1,800 per kg, but it fetches more than Rs 3,000 per kg in the international market. Thus, even as a raw product, *musli* can be a rich source of rural income. When processed in the form of Ayurvedic and other medicines, *musli* has the potential to generate tremendous incomes.

Because of its use in many Ayurvedic, Allopathic and Unani medicines, this wonder-herb has a total estimated annual market demand of approximately 35,000 tons. Present production is not even five percent (5 %) of the estimated demand. *Safed Musli* is a cash crop with low risk and high payback in a period less than one year. With the scientific mode of cultivation and careful selection of planting material this crop will yield repeated benefits, year after year. Since the huge demand for this herb is hastening its extinction, it should be grown ex-situ. This will not only benefit biodiversity but also will generate vast incomes in an equitable and eco-friendly manner.

Hospitals in Ancient India

By DP Agrawal and Pankaj Goyal

Since ancient times it has been the Indian tradition to take care of and treat patients in their own homes. For those who had nobody to look after them, the community and/or ruler arranged places for lodging and treatment.

A recent article by O.P. Jaggi, the well known historian of medicinal sciences, recapitulates the state of Indian hospitals during the ancient and the medieval periods. It is remarkable that, all through its history, the state in India has functioned as a welfare state, providing highly organised health facilities to the destitute and the poor. This article, based on Jaggi's comprehensive article, gives a brief glimpse of the ancient social medical systems in India.

Ancient Times

Fa-hien (405-411 CE), a Chinese traveller who visited India during the time of Candragupta, wrote in details about the charitable dispensaries in Pataliputra. According to his accounts, the nobles and householders of this country founded hospitals within their cities, to welcome and treat the destitute, poor, crippled and diseased from any and all countries. All patients were treated freely and provided with many kinds of assistance. After being cured by physicians, they left at will.

Hiuen Tsang (CE 629-645), another Chinese traveler and a contemporary of Emperor Harsha, also provides a description of India's hospitals of that time. According to him, in all the highways of the towns and the villages throughout India there were 'hospices' (*punya-salas*). These hospices served travelers and the poor with food and drinks as well as with medical care by physicians and free medicines. These institutions that helped the poor and the needy were also known by several other names such as *punyasthanas,*

punasalas, dharmasalas, viharas and maths. These were the Indian counterparts of the West's almshouses, monasteries and infirmaries of those times.

There are some epigraphical records showing the existence of dispensaries in the Deccan during the Pallava period between CE 574 and 879. Epigraphical records of the Chola period tell us about the allowances given to the physicians, village dispensaries as well as the town hospitals. The records of Chola kings show that words like *atulasalai* or v*aidyasalai* were used for dispensary, while words like *atula* or *vaidya* were used for medicines. There were a large number of dispensaries in the village, most of which were maintained by a local physician who inherited the role from the parents. However, sometimes the physicians were appointed by the king or the queen or by some religious institution or local authority.

The temple inscriptions of one of the temples of the Chola period give a detailed account, including description, about a hospital, a medical school and a hostel for students. For example, Veera Rajendra Deva of the Cholas issued a commandment in CE 1067 that is inscribed on the walls of the inner sanctuary of the temple of Venkateshwar at Tirumakudal in the district of Chingelput. It describes 15 beds in the hospital for the treating members of the temple, the students and the teachers of the school. The hospital was administered by Kodani Rameshwathan Bhattar (a physician) who was paid about 90 kalam of paddy per year; there was also a surgeon in the hospital (Calliyakkirivai Pannuvan) who was paid 30 kalam of paddy per year. In addition to the physician and the surgeon, there were two persons who collected medicinal herbs for processing, and two attendants who "waited" on the patients and administered medicines. The persons who collected the medicinal herbs were paid 6 kalam of paddy and 2 kasu, while the attendants were paid 30 kalam of paddy and one kasu. Some money was spent on other accounts such as a barber, who was paid 15 kalam of paddy and a waterman who was paid15 kalam of paddy. There was also a provision for a lamp to be kept burning in the hospital during the nights. Each patient was provided with daily rice. The names of twenty different medicines that were kept in the store of the hospital were also mentioned in that inscription.

Another inscription dated CE 1226, found on a stone pillar of Malakapur in Andhra records references of medical interest. According to this inscription Kakatiya Queen Rudramma and her father Ganapati donated several villages, south of the river Krisna, to Vishweshwara.The income accruing from these holdings was divided into three parts, one part of which was used for a maternity home, one part for a hospital, and the third part for a school. The prosperous, the princes and the kings who built various hospitals and supported them with money were considered pious and philanthropic.

Indian Influences on West Asia and Islam

It is interesting to review the important role played by the Arabs in learning Indian sciences and social customs and then disseminating these to the West.

The names of several Indian products such as Indian swords, spices and aloes-wood are often found in pre-Islamic poetry. After the emergence of Islam in West Asia, names of

several Indian drugs, such as *Kafur (Karpüra), Misk (Muska), Zanjabil (Srhgavera) and ud (Aguru*), entered the Qur'an and the Prophet's traditions (Ahadith-i-Nabawi). Probably Arabic words like *Faniz, Tütia, Narjil, Bish* and *Sandal* were derived from Sanskrit. Varma (1992) in his detailed article, *"Indo-Arab Relations In Medical Sciences"*, gives several well-documented instances of such influences.

Several Indian jatis, such as Jats (called Zutt in West Asia) had settled down in Arabia even before the beginning of Islam and were well-versed in different branches of ancient Indian traditional medicine. Many of them were using their clinical proficiency to cure Arab patients. The wife of the Prophet was cured by an Indian Jat physician of Medina. It is also recorded that Harith bin Kalada, the trusted Hakim of the Prophet, studied in the medical school of Jundishapur (Khuzistan, South-West Iran) where Indian *vaidyas* and philosophers also taught various sciences, including medicine. After completing his studies and before returning to Mecca, Harith travelled across India gathering more information about different branches of Indian Medicine. The records also mention that an Indian physician named Birzantin Hindi had migrated to Yemen and settled there, presumably during Anusherwan's reign (530-580 CE).

A Chinese monarch sent a book gift to the first Ummayyad Caliph (660-680 CE). The book contained some secrets and wisdom regarding Indian medicine, alchemy and astronomy. The same book was received by his grand son, Abu Hashimn Khalid bin Yazid, who was keenly interested in acquiring scientific knowledge from different countries. It is believed that he might have extracted and assimilated extensive material on Indian medical sciences and other Indian disciplines. It is stated that after conquering Sindh, 'Abdullah bin Sawwar 'Abdi (667 CE), the Governor of Sind, sent a number of rare gifts to the Caliph on behalf of the Raja Gigan (Qiqan). Al Tabari (c. 850 CE) mentions that the Indian hair dye (al-Khidab ul-Hindi) was also exported to Arabia and was very popular with the Arabs because of its peculiar ability to retain the bright dark texture of hair for at least a year.

All the Abbasid caliphs from al-Mansur (754-773 CE) to al-Mutawakkil (847-886 CE) were patrons of arts and sciences. Caliph Harun al-Rashid's (763-809 CE) is well known for his literary and scientific interests. He established the famous Bait-ul-Hikmat (House of Wisdom) - a combination library, academy and translation bureau. In many ways, this became the most important educational centre since the foundation of the Alexandrian museum in the first half of the third century BC. When the Arabs realized the high quality and value of Ayurveda and other aspects of Indian culture, they became interested in translating Indian medical and other scientific works from Sanskrit into Arabic. Therefore, works like *Caraka-samhita* and *Susruta-samhita* were rendered into Arabic and these translations highly impressed the Arabs who assimilated an enormous amount of this material into their Tibbi medical treatises.

The *Barmecide* (*Barmaki* or *Barmak*, after the Sanskrit word *Pramukh* or high priest) rose to the most influential position during the Abbäsid period, particularly in the reign of Caliph Harun al-Rashid. As a physician, Barmak's claim to fame is the pill which was named after him (Habb-i-Barmaki). It was recommended by Ibn Sina (980-1037 CE) and

later Hakims and widely used as a perfume by prostitutes. Yahya bin Khalid, the Barmecide (c. 805 CE), the vizier of the Caliph Mahdi and the tutor of Harun al-Rashid, sent an Arab scholar to India to study and bring back Indian drugs and herbs. Yahya also invited Indian *vaidyas* and philosophers westwards so that he might learn from them. When Harun al-Rashid was afflicted with a serious disease and could not be cured by his own physicians, he sent for the Indian trained physician Manaka (Mankhaor Minikya) with precious gifts. The physician came to Baghdad, cured the Royal patient and the caliph granted him a handsome pension and great wealth.

Manaka was proficient in Ayurveda, other Indian sciences, and Indian and Persian languages. He was deputed as Chief of the Royal Hospital at Baghdad and translated several books from Sanskrit into Persian and Arabic languages. Ibn Dhan (Dhanya, and a short form of Dhanvantari) was another competent Indian *vaidya* who lived jn Baghdad at the same time of Manaka. Yahya bin Khalid, the Barmecid vizier, invited him to be the Director of his (Barmecid) hospital at Baghdad. At his behest, Ibn Dhan also rendered a few Sanskrit texts into Persian and Arabic.

Saleh bin Behla was another competent practitioner of Ayurveda, though he does not seem to have had any official position. He is known to have cured Ibrahim bin Saleh of apoplexy even after he had been declared dead by the Caliph's own physicians. On the advice of Säleh, the royal patient was taken out of his coffin, bathed and dressed nromally. Then the Indian *vaidya* used a blowing pipe to blow some snuff made of Kundush (Verartilum album) into his nose. Suddenly, after about ten minutes, Ibrahim bin Saleh's body quivered and he sneezed, then, sitting before the caliph he kissed his hands. The caliph was very impressed by the clinical acumen of the Indian doctor and rewarded him handsomely.

An Indian raja sent the learned Indian *vaidya,* Durban, to the court of Caliph al- Ma'mun' in Baghdad. Burzoe, the well-known minister of Nausherwan (530-580 CE), was sent to India by his king to collect more information on Indian arts and sciences. He brought back Indian scientists and experts of Ayurveda along with books on different subjects of India. Most of these experts and scientists imparted Indian medical education. Other scholars translated scientific books in the Pehlavi language in the medical academy and translation bureau of Jundishapur. The Arab scholars were also acquainted with some other Indian *vaidyas* and masters of other allied sciences. These are:

1. Kanka (Ganga) was one of the more learned Indian scientists, skilled in the healing arts and drug sciences. According to some Arab writers, Kanka was accepted by all the Indian savants to be the highest authority in astronomy in ancient India. He probably authored the following books: (a) Kitab-ul Namudar fil-'Amar (The book of horoscopes of lives); (b) Kitab-ul Asrãri'l Mawalid (The book of the secrets of births): (c) Kitab-ul Qiranat (The book of conjuctions); Kabir wa Saghir (Major and Minor); (d) Kitab fi 'llm-ul-Tibb (The book on medical science); (e) Kitab fi'lm- Tawahhum (The book on mania); and (f) Kitab fi'l Ahdathi'Alamii fi l'Qirdn (The book on the incidents that may happen in the world under certain conjunctions of stars).

2. Sanjhal was another learned man of India who wrote a book on nativity - Kitab-ul- Mawalid (book of nativities).
3. Shanaq (Cãnakya) was one of the most able vaidyas of India. He was versatile in the various branches of science and philosophy. He excelled in astronomy and occupied a high position in the courts of Indian kings. Varma thinks that his book, Shanaq al-Hindi, is to be identified as Canakya, Candragupta's minister, also known as Kautilya. Manaka had translated this book into Persian from an Indian language, with Abu I (9th century CE) then translating it into Arabic. from the Persian by Abu I (9th cent.ury CE). Shanaq is the author of the Fihrist, Ibn al-Nadim, and other books on the conduct of life, the management of war, and cultural studies. Ibn abi Usaibi'ya refers to his works on the stars, lapidary crafts, and veterinary medicine.

The following Indian medical works were translated into Arabic from Sanskrit or Hindi during the Abbasid Caliphate:

1. Caraka-samhita was translated into Persian (Pehlavi) probably by Manaka Hindi and then it was rendered into Arabic by Abdu Habin;
2. Susruta sanhita (susrud);
3. Astanghrdaya;
4. Nidana;
5. Siddhyoga;
6. A book of poisons;
7. A book on the treatment of pregnant women;
8. A book on Women's diseases;
9. A book on snake bites and incantations;
10. Other books on intoxicants, diseases, drugs etc.

There are numerous records on the extensive trade and relations between India and the Arabs, for the purpose of procuring Indian objects and ideas. In fact, Caliph Harun 'al Rashid levied heavy taxes on various Indian articles, including spices and drugs. Caliph al-Ma'mun (813-33 CE) was very interested in different sciences, leading him to bring many scientists to his court from Jundishapür which had a large number of Indian scientists. After his return from India, Ibrãhim bin Fazârun brought a lot of information about Indian drugs and Ayurveda, its teachings and texts. Among the gifts sent by Indian Rajas to the Caliph al- Ma'mün, there was a special mat which was used for sleeping or sitting to prevent and cure pulmonary tuberculosis or phthisis. Indian kings used to send rare and wonderful Indian gifts to Arab caliphs. These gifts included aloe-wood, musk, camphor, dried ginger, kostos, amber, fresh myrobalan of Kabul and precious stones.

Firdaus-ul-Hikmat (Paradise of Wisdom) was a book composed by Abu 'Ali bin Rabban al-Tabari (CE 850) and is divided into a number of discourses. Its last and fourth discourse discusses the different branches of ancient medicine (Tibb-i-Vaidik) and has 36 chapters. Its first chapter starts with an introduction of Ayurvedic medicine as follows:

> "When I was about to complete this book, I thought it fit to add another discourse to it, with separate chapters describing the merits of medical works of Indians and their reputed medicaments. I hope it will increase the knowledge of the student because when he comes to know where these two great nations (Greeks and Indians) agree and where they differ, he will naturally come to know the advantages and disadvantages of Hindu medicine. Out of these topics which I have written here very many things agree with what the Greek Hakims have mentioned, but most of the things do not."

Regarding the origin and transmission of Ayurvedic medicine, Al-Tabari further adds:

> "They say that, in remote antiquity, the earth was always bright, fertile, clean and its five fundamental sources or elements, i.e. Mahabhuta's, natures were moderate. These were counted as five, with the addition of a kind of air, i.e. Ether (Akash) to the other four, namely (1) Earth (2) Water (3) Air and (4) Fire. The people lived in harmony and love with each other. They had no greed, anger, jealousy or anything else which would make their body and soul sick. But, later on, when jealousy arose among them, when they became greedy, they needed to find out the tricks and means to hoard up the riches,…grievances, scheming, weariness, causing pain to others, corrupted the community".

Al-Tabari's account is however ambiguous and and does not correspond with the authentic texts of Caraka-samhita. This may be because Al-Tabari's studies were presumably based on the defective Arabic translation of Caraka-samhita by 'Al bin Zain of Tabaristan, rendered during the days of Caliph Harun al- Rashid.

In addition to references to Shanaq, abstracts from other Indian books on poisons were borrowed and assimilated by Ibn Wahashiya (9th century CE) in his Arabic text, Kitab ul-Sumüm wa'l-Tiryaqat (book of poisons and their antidotes). Reference was also made to two Indian experts on the subject, Tammashah and Bahlindad and their medical treatises, in his Arabic work.

The famous Ibn Sinã (980-1037 CE), the Prince of Physicians, wrote the Canon of medicine (al-Qanun-fil-Tibb), which, for centuries, was the authoritative text on Unani medicine. In this text, Ibn Sinã expresses his indebtedness to the Indian doctors and quotes verbatim from Ayurvedic treatises on leeches and combination of various articles of food. Among the drugs that Ibn Sina describes, 49 were attributed to Indian origin. In Kitab ul- Saidana fi'l- Tibb (Book of Pharmacology in medical science), Abu Rayhan al-Biruni (973-1051 CE) referred to the skill and wisdom of the Indian physicians and their marvellous cures, for example, the use of aconite to cure haemorrhoids.

It may be safely concluded that the Arabs developed great respect and love for Indian medical scholars and their medical products, as is evident from many historical references and panegyrics (Qasida). Much of the Indian medical science, having been assimilated harmoniously into Arab science, subsequently returned to India repackaged as "Islamic" when the Muslim kings came to India.

The medieval hospitals were generally termed as Bimaristan or Maristan. The Arabs modernized these hospitals. The first hospital that resembles modern hospitals was built by Harun-al-Rashid in Baghdad in the beginning of the ninth century. A bigger hospital with more facilities was later established in Baghdad by the Buwayhid chief, Adud-ul-Dowlah in 978-979 CE. This hospital was known as Adudi Hospital and had a good staff. This hospital not only cured patients but also served as a teaching hospital for medical students who came from distant places. There was another hospital known as the Nuri Hospital built by king Nur al-Din Zinki in Damascus (CE 1111-1174). This was far superior to Adudi Hospital and served as a great service-cum-educational centre for nearly four centuries. Mansuri Hospital, founded by king Al-Mansur Qalawun at Cairo and a hospital at Marrakesh were some other fine hospitals of the Islamic period that were influenced by Arab imports of knowledge from India.

Adopting many practices from India, these hospitals in different states and cities, offered free treatment, food and medicines, during the medieval Islamic period. They had very good facilities: each had its own pharmacy with a special official known as Shaikh Saydalani (chief pharmacist), for managing drugs. The director of the hospital was known as Sa'ur al-Bimaristan and was assisted by a number of specialists including physicians, surgeons, oculist and bone-setters. Different administrators looked after various sections of the hospital and attendants were also provided to look after the patients. Many of the hospitals provided special types of hospital clothes to the patients and most of the hospitals had libraries of relevant medical books.

The early Muslim conquerors brought their Unani or Islamic system of medicine to India, including many things previously appropriated by West Asia from India. Along with their medicine system they also brought physicians and those who practised different healing arts. According to Ziya-ud-din Barani (a contemporary historian), the capital of Delhi had became the envy of Baghdad, the rival of Cairo, and the equal of Constantinople due to the presence of men of great talents. Some examples from the Islamic period in India are as follows:

1. Tughluq Dynasty Hospitals: During the time of Muhammad bin Tughluq (CE 1325-1352) there were about 70 hospitals in Delhi alone and 1200 physicians served as state employees. Feroz Shah Tughluq was the next ruler and he established a hospital for the sick and troubled, both natives and strangers. A large portion of the kingdom's revenues paid for salaries, and 4200 afflicted persons received monthly allowances. The needy received medicine, food, and drinks and the ruler endowed some richly cultivated villages to the hospitals at the expense of the treasury.
2. Dar-u-Shifa, the Grand Hospital: In CE 1595, Sultan Muhammad Qutab Shah IV built a hospital known as Dar-u-Shifa (house of cure) on the banks of the Mossi River. According to the journal "Mahanama," Dar-u-Shifa had accomodation for 4000 patients and many physicians. It was perhaps the biggest hospital in the world. The journal further stated that there were about 52 public rest houses, where travellers from outside and far off places could rest in comfort and they were very well provided with food and other necessities of the life. The

physicians were classified into two categories: (i) physicians who were highly qualified and who looked after the patients, and (ii) scholars who were learned in science and medicine.

3. Mughal Hospitals: During Akbar's period the Unani medicine system spread through the greater part of India. Many renowned hakims and scholars came from Persia and other Central Asian countries. Jahangir and Shah Jahan built more hospitals. Besides the emperors many prosperous nobles and citizens also built hospitals.

Thus we see that both in ancient and medieval India, the state, as well as the rich people, provided medical facilities for the poor and the common man. The state in India always realised its responsibility to its citizens and functioned as a welfare state.

Dyes and Detergents: Traditional Himalayan Technology

By Lalit Tiwari

The Central Himalayan region is one of the richest regions for studying indigenous technologies. This region has its own traditional medicine system with more than a thousand medicinal plants and many traditional therapies, including cures for diseases classified as incurable. Other traditional technologies include earthquake-proof architecture, watermills, mining and metallurgical activities.

One of the important traditional techniques of this region is wool and cloth dyeing and washing, which many jatis practice using plants and plant products. These ancient techniques are preserved and transmitted only orally. Basically, these techniques are eco-friendly and beneficial to society. Modernization is destroying and replacing these eco-friendly techniques, replacing them with chemical products that are harmful to humans and the environment.

Traditional Dyeing Techniques:

Various communities make a range of woollen garments and materials, in addition to processing and colouring wool and cloth. The indigenous knowledge of making natural dyes from native plant species originally developed in the high altitude regions of Kumaun over a long period of time. These practices were very common in the high altitude districts of Pithoragarh in Kumaun, Chamoli and Uttarkashi districts of Garhwal. They had perfected their knowledge to such a level that they could get most of the bright shades of colours for their woollen products. Before the 1962 China-India War, there was trans-border trade between India and Tibet, and the import of wool for the traditional cottage industry was a major source of income for the Bhotiya tribe.

The plant pigments used for dyeing textiles, wool and fibres are derived from the root, bark, flower, stem, leaf, fruit, etc of the plant. C. P. Kala describes the following eight plants of the Himalayan region which are used in traditional practice of dyeing:

Table 1. Himalayan plants used for dyeing. Source: C.P.Kala (2002), Current Science, 83(7): 815.

Local Name of Plant	**Part Used**	**Colour Produced**
Kilmora; Kingod	Root	Yellow
Kapasi	Fruit shell	Camel
	Root	Red
Akhrot	Fruit shell	Camel
Dolu	Root	Yellow

Archa	Root	Yellow
Khukhuyinya	Root	Yellow
Bajar Bhang	Root	Brown

By mixing these base colour dyes a number of intermediate colours and shades are produced. According to Kala, raw wool has two colours, black and white. Only white coloured wool is used for dyeing, in order to get different shades of colours. The wool is first washed with Reetha (Sapindus mukorosii) seeds, and then dried in the sun.

The dyeing material like root, fruit shell, seeds, etc are washed thoroughly with tap water and then sun dried. This dried plant material is then powdered and mixed with water to make a solution. Next, the solution is heated in a vessel until it begins to boil. Then, the wool or cloth is immersed in the solution for dyeing. The wool and cloth are stirred thoroughly for a long time to ensure thorough and uniform soaking. Sometimes a bit of ash is poured in the prepared solution for better colouring. After the dyeing is completed, the wool or cloth is removed from the boiling cauldron and dried under the shade. For retaining the brightness in colour, direct drying in sunlight is not recommended.

The main source of wool is sheep. The sheep of high altitude areas are white, and therefore produce more white wool. However, black wool is in greater demand. The Bhotiyas of the Himalayan region generally weave more then 10 woollen items such as Gudma, Thulma, Pankhi, Pattu, sweater, cap, muffler, scarf, carpet, Ashan and Pakhi. Among these only four items (carpet, Ashan, sweater and Pakhi) are generally dyed. The Bhotiya women weave these woollen items in winter season. The finished product is then sold in regional, nearby, or remote markets.

Joshi and Pande describe many other natural colours used in the traditional cloth dyeing art and also in paintings in the Central Himalayan region.[1] These traditional natural colours are totally harmless and eco-friendly in comparison to the modern chemical based colours. Yet, for the past 25 years, the Himalayan people have been using the synthetic dyes purchased from the market. Kala compares the synthetic and natural dyes in the following table.

Table 2. Comparison of natural and chemical dyes. Source: C.P.Kala (2002), Current Science, 83(7): 817.

Natural Dye	**Synthetic Dye**
Prepared from forest biomass such as plants and lichens.	Manufactured in laboratories by use of chemicals.
An eco-friendly product, as it is made up of natural substances.	Not eco-friendly, as the chemicals used in its manufacturing can pollute air and water.
Long life and never loses colour	Often loses colour
Provides limited colours and is less bright	Provides multiple colours with bright tint.

[1] Joshi & Pande (1999), Ethnobotany of Kumaon Himalaya. Pp.439-449.

compared to synthetic dyes.	
Colours are harmless to human body.	Colours can be harmful to human body

Traditional Washing Techniques:

Besides the dyeing methods, the Himalayan people also use traditional methods for washing their clothes. Pande and Pokhariya describe some plants and plant products, used in this washing clothes, in the following table:

Table 4. Plant detergents. Source: Pande & Pokhariya (1999), Ethnobotany of Kumaon Himalaya. P.485.

Local Name of Plants	**Part used**
Reetha	Fruit shell
Sarso	Ash of plant
Chyura	Ash of plant
Til	Ash of plant
Tun	Ash of bark
Chawal	Grain
Atin	Ash
Bhorad	Ash
Bhimal	Ash
Rambans	Ash
Awala	Ash
Madua	Ash

Conclusion:

The woollen cottage industry is the backbone of the Himalayan people and one of the more remarkable features of this industry is the use of natural dyes, which are eco-friendly and never lose colour in comparison to the synthetic dyes.

Needham on Early Indian Inventions of Hydraulics, Cotton-Gins and Alcohol Distillation

By D.P. Agrawal

Joseph Needham was a great scholar who brought Oriental Science to the notice of the West. A recent article by Habib provides some insights into the relevance of Needham's work in understanding Indian history of science and technology:

> The great venture of the late Joseph Needham, the publication of the monumental series, Science and Civilisation in China, began in 1954. As the volumes came out it became clear that Needham was not simply concerned with the development of science and technology in China, but wished to set it in a worldwide context, with special attention paid to inter-cultural exchanges. It, therefore, became necessary for him to establish the sequence of developments that had taken place in civilisations other than the Chinese. While for Europe there was a vast amount of work already done, whose results he could use, this was by no means the case with India, Iran and Central Asia. And yet Needham extensively explored the scientific and technological aspects of the Indian and Islamic civilisations, going to texts and many out-of-the-way secondary sources. His statements on India, often occurring as asides, were never carelessly made, and invariably gave a critical assessment of the existing state of research; and he often gave good guidance on areas that needed to be explored (Habib, p.246).

Noria and Saqiya: Water Lifting Devices

Regarding water-lifting devices, Habib informs us that in the very few studies of the history of water-lifting devices in India, such as Ananda K. Coomaraswamy's pioneering note on the Persian wheel, there is no differentation between different kinds of water-wheels. Whenever they referred to the water-wheel, Coomaraswamy and others understood it to be the Persian wheel, which is a geared saqiya.

A.P. Usher highlighted the confusion between the two forms of water-wheels - "the noria or Egyptian wheel and the chain of pots." Needham, in *Science and Civilisation*, Vol. IV (2), clearly differentiated between the two forms - the noria having the containers fixed to the rim of the wheel and the saqiya on the rope or chain flung over the wheel (p. 356). Having made this distinction, he then used evidence from Coomaraswamy and Laufer to argue that the earliest water-wheel in India was the noria, and probably indigenous to India.

Needham gave two reasons for this conclusion. First, the noria was in the Greek world in the first century BCE and in China in the second century CE. Because these dates are so close and the Greek and Chinese so far apart geographically, he conjectured the role of an intermediary civilization in this diffusion. Second, he located the earliest recorded reference (derived presumably from Coomaraswamy) to the noria in the term cakkavattaka (turning wheel), used in the Cullavagga Nikaya (assigned to ca. 350 BCE) to refer to one of the three permissible models of water-lift. Though these details do not

appear in Needhams work, this term was actually glossed by Buddhaghosa (fifth century CE) as arahattaghatiyanta, and explained by Kassapa (twelfth century), as "a well-wheel with water-pots attached to its spokes." It is clear that since ara means "spoke" and ghata, "earthen pot," araghata (or, in its Prakrit form, arahatta or arahattaghati), must mean a wheel "with earthen pots on the spokes." So Buddhaghosa's explanation, even without Kassapa's later commentary, was sufficient to show that at least he conceived the cakkavattaka as a noria. L. Gopal cites a passage from the earliest version of the Pancatantra, datable to ca. 300 CE, which speaks of a man operating an araghatta (araghattavaha). This term, which must originally have been used for the noria, is of a very early date.

On the other hand, there is still no firm evidence in India for the chain of pots or "potgarland" (to use Schioler's terminology) earlier than the sixth century, when Yasodharman's Mandasor incription dated 589 in the Malava Era (=532 AD) first attests it. With Bana in the next century, the references to the potgarland become fairly numerous ("rosary like the rope on which the pots are placed").

Gearing mechanism is not yet present, for Bana says explicitly that both the "rosary" and the "water-pot device" (ghati-yantra) were turned by the right hand. It must be remembered that human drive would imply vertical rotation (and so no gearing), while animal power, usable only with horizontal rotation, needed gearing to convert the horizontal into vertical motion. The well-known Mandor frieze (twelfth century) indeed shows a wheel with a potgarland worked by two men, with flowing water for camels to drink. There is naturally no gearing here. The earliest explicit description of the gearing mechanism of the "Persian wheel" or geared saqiya is still that of Babur (d. 1526).

Habib extends Needham's thesis by postulating a chronological sequence in three stages:

Invention	**Date**
Noria alone	4th century BC to 4th century CE
- The pots previously attached to the spokes and rim now transferred to the chain ("potgarland") - Use of this ungeared saqiya attested	6th to 7th century CE 12th century CE
Introduction of the gearing mechanism, and thereby the full-fledged saqiya or Persian wheel, making possible the use of animal power	Some time before 1500 CE

This may be summarized as follows:

1. There does not seem to be any indication that around 350 BC the noria's presence could be found in any civilization other than India. So Needham was right in ascribing an Indian origin to the noria.
2. Despite elaborate arguments claiming an Indian origin of the saqiya (e.g. by L. Gopal), Needham's suggestion that India did not invent the saqiya has stood the test of subsequent research fairly well.

Worm-Gearing and Crank

Habib is impressed that despite having no references to the history of worm-gearing in India, Needham (*Science and Civilisation*, IV (2), pp. 122-24) proposed that the device originated in India. Needham's argument was based on the presence of the charkhi or cotton-gin with two elongated worms for turning its rollers in opposite directions. Noting its presence in Indo-China and Xinjiang, Needham speculated that it reached China from India by two routes, via Burma and Indo-China, in about the fifth century CE and via Central Asia in the thirteenth century CE. This would mean that the cotton-gin would have been in use in India before the sixth century; but there was no evidence to prove this at the time of Needham's writing.

According to Needham, this "most ancient form of rolling mill," was technologically significant, hence the importanc in testing this hypothesis. Schlingloff identified a scene in an Ajanta painting as showing cotton-processing activities. However, "the rectangular frame, the upper part of which is a double string [rect. Roller]" could not be the scotching bow Schlingloff believed it to be. Ishrat Alam rightly identified this as the Indian cotton gin: the rollers are thin because, lacking a crank-handle, the upper roller had to be rotated by hand. Thus, we have the geared cotton-gin being dated to the sixth century, in conformity with Needham's hypothesis. It was not yet the instrument identified in later days, since it had no crank-handle. We must suppose that this was possibly one reason why, when China received it, it had no worm-gear and was given two crank-handles, or a handle and a pedal, to rotate the two rollers (pp. 252-260).

The Scutch-Bow

The case of the cotton-carder's bow is similar. Habib explains that Needham's attribution of its origin to India was confirmed by research. The earlier perception, as presented by R. J. Forbes, was that the bow was present in pre-historic Bronze-Age Europe for separating wool-fibers. Then it inexplicably disappeared in the classical age, and suddenly reappeared in Europe in the fifteenth century. Habib pursued the Arabic dictionary definitions to show that "bowing" first appears only in the Qamus of al-Firuzabadi, ca. 1366-67. Needham was later able to trace an eleventh-century reference to the device, stating that it came to China "with cotton itself," which could be either that of the sixth century or of the thirteenth. But, he theorizes "this was probably an Indian technique" (*Science and Civilisation*, IV (2), p. 127). This was confirmed by Schingloff's references to the scotch-bow in the Jatakas and in the Milindapanho texts that date back to the early centuries of the Common Era. He also cited Hemacandra's Abhidhanacintamani, written in the twelfth century. It is plausible that there was also a slow diffusion of these inventions to Sind (early eighth century), Iran and Central Asia (by the eleventh century), the Arab World (fourteenth century), and Western Europe (early fifteenth century). Whatever one may think of these details, the essential hypothesis of Needham stands vindicated (Pp. 262-263).

Distillation

Even more startling is the fact that Needham attributes the distillation of alcohol to India. In Vol. V (4) of *Science and Civilisation* (especially pages 85-6,97,104-7 and 131-2), Needham details the history of liquor distillation in India, thereby challenging the then prevalent theory that alcohol production originated in the Mediterranean world in the 13th century. Habib explains that Needham respected the views of Mehdihassan, who written extensively on the possibility of early liquor-distillation in India. He had, of course, before him Ray's *History of Hindu Chemistry*, with its citations of early medieval texts on distillation. None of this gave any certainty of India's role in the early history of alcohol production.

In his theory, Needham carefully analyzes the archaeological evidence of stills from Taxashila, first highlighted by Marshall and A. Ghosh. This is now heavily reinforced by Raymond Allchin and the numerous remains of stills from the Shaikhan Dheri (Charsadda, NWFP, Pakistan) excavation. Needham calls these stills "Gandhara stills," comparing them with the western or Hellenistic still of his still-classification, saying they were essentially "retorts." He further states that their early dating (150 BC-150 CE), might well make them the origin of all such forms of stills. The pottery remains at Shaikhan Dheri were so extensive (, viz. one alembic, 130 receivers so capacious), that one must assume that alcohol and mercury, for example, was the intended product. This would give precedence to India over all other countries in liquor distillation.

Needham does not clarify the degree of alcohol purity in the Gandhara stills. It could have yielded highly diluted alcohol, or, if the fire was kept low to reduce dilution, then the rate of alcohol production would have been very slow.

The modifications that were introduced in Italy in the 12th century (possibly influenced by the close exchange of ideas with the Arabs, as some evidence indicates) were designed to improve cooling, thereby increasing pure alcohol collection at a low level of heat. The "Moore's head" had a water-container set over a spoon-like alembic, a concave roof and annular rim-collection connected by a tube with the receiver. This undoubtedly led a much higher degree of purity in distilled alcohol than under any other device.

It is true that by this time there were alternative forms of stills also available. These forms are what he calls the "Mongol still" (condensation in a catch-bowl within the still) and the "Chinese still" (with the catch-bowl connected by the side-tube with receiver outside). The former depicted on the wall of a cave of the period 1031-1227 and the latter shown in a drawing of 1163 in China (*Science and Civilisation*, V(4), pp. 62-68, 78-79). But neither of these devices could have probably competed successfully with the improved stills from the Mediterranean.

Needham examines the famous passage of ca. 1595 in the A'in-I Akbari of Abu'l Fazl, translated by Blochmann, in which three kinds of liquor-stills are described (pp. 106-7). Needham identified these as the Mongol, the Chinese and the Hellenistic types. Habib disagrees, saying that while the first may be identified as "Mongol," the second is clearly Gandharan. Abu'l Fazl expressly states that the condenser was the receiver itself placed in cold water. The third, which Needham identifies as "Hellenistic" is still more interesting,

since it clearly has the Moore's head (water at the top and still-head shaped like a "spoon", so expressly described). It is, in other words, the medieval Italian-Arab still.

Needham observes that it was the Gandhara still, which some time between the seventh and 12th centuries, was recognized as more practical than the Mongol and Chinese types and "adopted accordingly" (Pp. 265-268).

It may be mentioned here that the early invention of distillation must have helped production of pure zinc by distillation, as discussed in the work of Jeewan Karakwal.

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INDRANI STOPPED HERE ON NOV 13TH

The Kerala School, European Mathematics and Navigation

By D.P. Agrawal

Kerala, the southwest coast of the Indian peninsula, has been a centre of maritime trade, with its rich variety of spices greatly in demand, from the time of the Babylonians. Famous travellers and explorers such as Ibn Battuta and Vasco da Gama came there from across the Arabian Sea. In recent years, Kerala has been recognized as a vibrant center of medieval Indian mathematics.

Joseph (1994) has brought out, emphatically, the significance of the Kerala School of Mathematics in *The Crest of the Peacock*, though Eurocentric scholars have severely criticized it. C.K. Raju, the well known mathematician and historian of science, has also written a good deal not only on the famous work, *Yuktibhasa* by Jyesthadeva, but also on the export of mathematics from India to Europe.

Until recently there was the erroneous notion that mathematics in India did not progress after Bhaskaracharya. Allegedly, it was because Indian scholars seemed contented in regurgitating old theories with endless commentaries, and had to be pulled out of their frozen state by the British who gifted them modern mathematics.

Contradicting this notion, the period between the 14th and 17th centuries marked a high point in the indigenous development of astronomy and mathematics in India and the case of Kerala is especially well documented. The quality of the mathematics in the texts that have been studied is of such a high level, compared with earlier periods, that it would be impossible to explain the quantum leaps required to move from the theoretical frozen state to enlightenment from invaders. Imports from external sources such as Greece or Babylonia cannot explain the Kerala phenomenon because many future “discoveries” (or appropriations) in European mathematics were pioneered by Kerala astronomer-mathematicians 200 to 300 years earlier. This begs the question of whether the developments in Kerala had any influence on European mathematics. The leading scholar who has dealt with this issue is C.K. Raju, whose views are also discussed in this essay.

Joseph (1994) states that in 1835, Charles Whish published an article in which he referred to four works – Nilakantha's *Tantra Samgraha*, Jyesthadeva's *Yuktibhasa*, Putumana Somayaji's *Karana Paddhati* and Sankara Varman' s *Sadratnamala* – as being among the main astronomical and mathematical texts of the Kerala School. While there are some doubts about Whish's views on the dating and authorship of these works, his main conclusions are still broadly valid. Whish sees the *Tantra Samgraha* laying the foundation for a complete system of fluxions ['Fluxion' was the term used by Isaac Newton for the rate of change (derivative) of a continuously varying quantity, or function, which he called a 'fluent']. He writes that the *Sadratnamala*, a summary of a number of earlier works, "abounds with fluxional forms and series to be found in no work of foreign countries." The Kerala discoveries include what are erroneously named after Europeans as the Gregory and Leibniz series for the inverse tangent, the Leibniz power series for p, and the Newton power series for the sine and cosine, as well as certain

remarkable rational approximations of trigonometric functions, including the well-known Taylor series approximations for the sine and cosine functions. It is interesting that these results were apparently obtained without the use of infinitesimal calculus.

In the 1940s it was Rajagopal and his collaborators who highlighted the contributions of Kerala mathematics, though their results are yet to be acknowledged in Western histories of mathematics. For example, Boyer (1968:244) states, "Bhaskara was the last significant medieval mathematician from India, and his work represents the culmination of earlier Hindu contributions." And according to Eves (1983:164), "Hindu mathematics after Bhaskara made only spotty progress until modem times." Eurocentric resistance to Indians' rational accomplishments is immense as this underpins the whole civilizational supremacy of the West.

Several later writers refer to Madhava's work on power series for p and for sine and cosine functions. However, the original sources remain undiscovered or unstudied. Nilakantha (1445-1555) was mainly an astronomer, but his *Aryabhatiya Bhasya* and *Tantra Samgraha* address infinite-series expansions, problems of algebra and spherical geometry. Jyesthadeva's (c. 1550) text, *Yuktibhasa*, is one of those rare texts in Indian mathematics or astronomy that gives detailed derivations of many theorems and formulae in use at the time. This work is based mainly on the *Tantra Samgraha* of Nilakantha. *Kriyakramakari*, a joint commentary on Bhaskaracharya's *Lilavati* by Narayana (c. 1500-75) and Sankara Variar (c. 1500-1560), also contains a discussion of Madhava's work. The Karana *Paddhati* by Putumana Somayaji (c. 1660-1740) provides a detailed discussion on the various trigonometric series. Finally there is Sankara Varman, the author of *Sadratnamala*, who lived at the beginning of the 19th century and may be considered the last of the notable names in Kerala mathematics. His work (in five chapters) summarizes most of the results of the Kerala School, but without any proofs.

Astronomy provided the main motive for the study of infinite-series expansions of p and rational approximations for different trigonometric functions. For astronomical work, it was necessary to have both an accurate value for p and highly detailed trigonometric tables. In this area Kerala mathematicians made the following original discoveries:

1. The power series for the inverse tangent, usually attributed to Gregory and Leibniz;
2. The power series for p, usually attributed to Leibniz, and a number of rational approximations to p; and
3. The power series for sine and cosine, usually attributed to Newton, and approximations for sine and cosine functions (to the second order of small quantities), usually attributed to Taylor; this work was extended to a third-order series approximation of the sine function, usually attributed to Gregory.

Apart from the work on infinite series, there were extensions of earlier works, notably of Bhaskaracharya:

1. The discovery of the formula for the circum-radius of a cyclic quadrilateral, which goes under the name of l'Huilier's formula;
2. The use of the Newton-Gauss interpolation formula (to the second order) by Govindaswami; and
3. The statement of the mean value theorem of differential calculus, first recorded by Paramesvara (1360-1455) in his commentary on Bhaskaracharya's *Lilavati*.

It is relevant to note some points of the debate between CK Raju and the West, and in particular, the debate between Raju and Whiteside (the famous historian of Maths), about the export of Indian mathematics to Europe.

Raju's Encounter with Eurocentric scholars

Raju explains that Whiteside, while conceding Madhava's priority in developing infinite series, distorts the dates of both Madhava and the *Yuktibhasa*, by about a century in each case. (Madhava was 14th-15th c. CE and not 13th, while the Tantrasangraha [1501 CE] and *Yuktibhasa* [ca. 1530 CE] are both 16th c. CE texts, not 17th.) In fact, in the 16th c. CE, Jesuits were busy translating and transmitting a massive number of Indian texts to Europe. During the 16th c. CE, their activities were especially concentrated in the vicinity of their Cochin College, where they were teaching Malayalam to the local children (especially Syrian Christians) whose mother tongue it was, and where copies of the *Yuktibhasa* and several other related texts were and still are in common use, for calendar-making and other applications.

After the trigonometric values in the 16th and early 17th c. CE, the identical infinite series in these Indian texts started appearing, from 1630 onwards, in the works of Cavalieri, Fermat, Pascal, Gregory etc, who access to the Jesuit archives at the Collegio Romano. Since Whiteside has a copy of the printed commentary on the *Yuktibhasa*, he could hardly have failed to notice this similarity with the European works with which he seeks to make the *Yuktibhasa* contemporaneous!

Raju has no doubt that in the course of "the fabrication of ancient Greece" (in Martin Bernal's words), some Western historians were skilled in juggling the dates of key texts. Having anticipated this, the evidence for the transmission of the calculus from India to Europe is far more robust than the sort of evidence on which "Greek" history is built – it cannot be upset by quibbling about the exact date of a single well-known manuscript like the *Yuktibhasa*.

While the case for the origin of calculus in India, and its transmission to Europe is otherwise clear, there remains the important question of epistemology - Was it really the calculus that Indians discovered?" While European mathematicians accepted the practical value of the Indian infinite series as a technique of calculation, many of them did not, even then, accept the accompanying methods of proof. Hence, like the algorismus which took some five centuries to be assimilated in Europe, the calculus took some three centuries to be assimilated within the European frame of mathematics. Raju has discussed this question in depth, in relation to formalist mathematical epistemology from Plato to

Hilbert, in an article *"Computers, Mathematics Education, and the Alternative Epistemology of the Calculus in the Yuktibhasa".*

In this paper, Raju proposes a new understanding of mathematics. He argues that formal deductive proof does not incorporate certainty, since the underlying logic is arbitrary, and the theorems that can be derived from a particular set of axioms would change if one were to use Buddhist logic, or, say, Jain logic.

Raju further states,

> "Indeed, I should point out that my interest in all this is not to establish priority, as Western historians have unceasingly sought to do, but to understand the historical development of mathematics and its epistemology. The development of the infinite series and more precise computations of the circumference of the circle, by Aryabhata's school over several hundred years, is readily understood as a natural consequence of Aryabhata's work, which first introduced the trigonometric functions and methods of calculating their approximate numerical values. The transmission of the calculus to Europe is also readily understood as a natural consequence of the European need to learn about navigation, the calendar, and the circumference of the earth. The centuries of difficulty in accepting the calculus in Europe is more naturally understood in analogy with the centuries of difficulty in accepting the algorismus, due, in both cases, to the difficulty in assimilating an imported epistemology. Though such an understanding of the past varies strikingly from the usual "heroic" picture that has been propagated by Western historians, it is far more real, hence more futuristically oriented, for it also helps us to understand e.g. how to tackle the epistemological challenge posed today in interpreting the validity of the results of large-scale numerical computation, and hence to decide, e.g., how mathematics education must today be conducted.
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> ”I would not like to go further here into the difficult question of epistemology, and the interaction between history and philosophy of mathematics, except to link it to Whiteside's use of the phrase "Hindu matmatics" [sic]. Am I to understand that Whiteside now implicitly accepts also the possible influence of Newton's theology on his mathematics, and is alluding, albeit indirectly, to some subtle new changes brought about by Newton in the prevailing atmosphere of, shall we say, "Christian mathematics"? Probably not. I presume instead that, despite his protestations to the contrary, Whiteside is really referring to the Eurocentric belief that there is only one "mainstream" mathematics, and everything else needs to be qualified as "Hindu mathematics", "Islamic mathematics" etc.
>
> ”Now it is true that I have commented on formalist mathematical epistemology from the perspective of Buddhist, Jain, Nyaya and Lokayata notions of proof (*pramana*) in my earlier cited paper and book. I have also commented elsewhere, from the perspective of Nagarjuna's *sunyavada*, on the re-interpretation of *sunya* as zero in formal arithmetic, and the difficulties that this created in the European understanding of both algorismus and calculus, difficulties that persist to this day in e.g. the current way of handling division by zero in the Java computing language. Nevertheless, having also scanned the OED for the meaning of

"Hindu", I still don't quite know what this term "Hindu" means, especially in Whiteside's "ruggedly individualistic" non-Eurocentric sense, and especially when it is linked with mathematics! Given the fundamental differences between the four schools listed above, it is very hard for me to dump them all, like Whiteside, into a single category of "Hindu"; on the other hand, if we exclude some, which counts as "Hindu" and which not, and why? And exactly how does that relate to mathematics?

'A key element of the Project of History of Indian Science, Philosophy, and Culture, as I stated earlier, is to get rid of this sort of conceptual clutter ,authoritatively sought to be imposed by colonialists (and their victims/collaborators), and to rewrite history from a fresh, pluralistic perspective. In my case, it is part of this fresh perspective to redefine the nature of present-day university mathematics by shifting away from formal and spiritual mathematics-as-proof to practical and empirical mathematics-as-calculation. Since my objective is truth and understanding, I am ever willing to correct myself, and I remain open to all legitimate criticism, but I do not recognize dramatic poses, assertions of authority, abuse, cavil, misleading circumlocutions, etc. as any part of such legitimate criticism.

”There are numerous other points in Whiteside's prolix response, to which it would be inappropriate to provide detailed corrections here. [E.g., I do not share the historical view needed to speak of the "re-birth" of European mathematics in the 16th and 17th c., which view Whiteside freely attributes to me, though I would accept that direct trade with India in spices also created a direct route for Indian mathematics, bypassing the earlier Arab route.] For the record, I deny as similarly inaccurate all the interpolations and distortions he has introduced into what I have said.

”There is, however, one issue, which remains puzzling, even from a purely Eurocentric perspective. In what sense did Newton invent the calculus? Clearly, the calculus as a method of calculation preceded Newton, even in Europe. Clearly, also, the calculus/analysis as something epistemologically secure, within the formalist frame of ’mathematics as proof’, postdates Dedekind and the formalist approach to real numbers. While Newton did apply the calculus to physics, that would no more make him the inventor of the calculus than the application of the computer to a difficult problem of genetics, and possible adaptations to its design, would today make someone the inventor of the computer. Doubtless Newton's authority conferred a certain social respectability on the calculus. The credit that Newton gets for the calculus depends also upon his quarrel with Leibniz, and the rather dubious methods of "debate" he used in the process. But none of this convincingly establishes the credit for calculus given to Newton, even within the Eurocentric (as distinct from Anglocentric) frame. So what basis is there to give credit to Newton for originating the calculus, while denying it, for example, to Cavalieri, Fermat, Pascal, and Leibniz?”

Navigation and Calculus

In a recent talk Raju(2000) emphasised that calculus has played a key role in the development of the sciences, starting from the "Newtonian Revolution." According to conventional wisdom, calculus was invented independently by Leibniz and Newton. This story of indigenous development, *ab initio*, is now beginning to totter, like the story of the "Copernican Revolution". The English- speaking world has known for over one and a half centuries that "Taylor" series expansions for sine, cosine and arctangent functions were found in Indian mathematics/astronomy/timekeeping (*jyotisa*) texts, and specifically the works of Madhava, Neelkantha, Jyeshtadeva etc. No one else, however, has so far studied the connection between these Indian developments and European mathematics.

The mathematics connection between India and Europe was linked to Europe's navigational needs – the most immediate need of the time. Columbus and Vasco da Gama used dead reckoning and were ignorant of celestial navigation. Navigation, however, was the strategic and economic key to European prosperity at that time. This led many European governments, who acknowledged their ignorance of navigation, to announce huge rewards for the development of appropriate navigational techniques.

The Jesuits, needed to understand how the local Indian calendar was made, especially since their own calendar was so miserably off the mark, partly due to the difficulties in handling fractions when using Roman numerals. In addition, European navigational theorists like Nunes, Mercator, Stevin, and Clavius were then well aware of the acute need not only for a good calendar, but also for precise trigonometric values, at a level of precision then found only in these Indian texts. The European governments needed this knowledge to improve their navigational expertise, since they were eagerly seeking to develop reliable trade routes to India - the pathway for the big European dream of getting rich. At the start of this period, Vasco da Gama, lacking knowledge of celestial navigation, could not navigate the Indian Ocean, and needed an Indian pilot to guide him across the sea from Melinde in Africa, to Calicut in India.

The rewards for providing the European government with navigational expertise was spread over time from the appointment of Nunes as Professor of Mathematics in 1529, to the Spanish government's prize of 1567 through its revised prize of 1598, the Dutch prize of 1636, Mazarin's prize to Morin of 1645, the French offer (through Colbert) of 1666, and the British prize legislated in 1711. Many key scientists of the time (Huygens, Galileo, etc.) were involved in these efforts. The navigational problem was the specific focus of the French Royal Academy, and a key reason for starting the British Royal Society.

Prior to the clock technology of the 18th century, the navigational problem in the 16th and 17th c. was addressed by focusing on mathematics and astronomy. The latter two were correctly seen as holding the key to celestial navigation. Furthermore, navigational theorists and mathematicians like Stevin and Mersenne correctly identified the presence of this knowledge in the ancient mathematical and astronomical or time-keeping (jyotisa) texts of the East. Though the longitude problem has recently been highlighted, this was preceded by a latitude problem, and the problem of loxodromes.

The solution of the latitude problem required a reformed calendar. The European calendar was off by 10 days, and this led to large inaccuracies (more than 3 degrees) in calculating latitude from measuring solar altitude at noon, using, for example, the method described in the Laghu Bhaskariya of Bhaskara I. However, reforming the calendar required a change in the dates of the equinoxes, hence a change in the date of Easter, and this was authorised by the Council of Trent in 1545. This period saw the rise of the Jesuits. Clavius studied in Coimbra under the mathematician, astronomer and navigational theorist Pedro Nunes, and Clavius subsequently reformed the Jesuit mathematical syllabus at the Collegio Romano. Clavius also headed the committee that authored the Gregorian Calendar Reform of 1582, and maintained contact with his teacher, Nune,s during this period.

Jesuits, such as Matteo Ricci, who trained in mathematics and astronomy under Clavius' new syllabus [Matteo Ricci also visited Coimbra and learnt navigation], were sent to India. In a 1581 letter, Ricci explicitly acknowledged that he was trying to understand local methods of timekeeping (jyotisa), from "an intelligent Brahmin or an honest Moor", in the vicinity of Cochin, which was, then, the key centre for mathematics and astronomy, since the Vijaynagar empire had sheltered it from the continuous onslaughts of Islamic raiders from the North. Language was not a problem, since the Jesuits had established a substantial presence in India, had a college in Cochin, and had even started printing presses in local languages, like Malayalam and Tamil by the 1570's.

In addition to the latitude problem, settled by the Gregorian Calendar Reform, there remained the question of loxodromes, which became the focus of navigational theorists like Nunes, Mercator etc. The problem of calculating loxodromes is exactly the problem of the fundamental theorem of calculus. Loxodromes were calculated using sine tables, and Nunes, Stevin, Clavius etc. were greatly concerned with accurate sine values for this purpose, and each of them published lengthy sine tables. Madhava's sine tables, using the series expansion of the sine function was the most accurate way to calculate sine values, at that time.

Europeans found it difficult to use these precise sine value for determining longitude in Indo-Arabic navigational techniques or in the *Laghu Bhaskariya.* This was because this technique of longitude determination also required an accurate estimate of the size of the earth, and Columbus had underestimated the size of the earth to facilitate funding for his project of sailing West. Columbus' incorrect estimate was corrected, in Europe, only towards the end of the 17th c. CE. Even so, the Indo-Arabic navigational technique required calculation, while Europeans lacked the ability to calculate, since algorismus texts had only recently triumphed over abacus texts and the European tradition of mathematics was "spiritual" and "formal" rather than practical - as Clavius had acknowledged in the 16th c. and as Swift (*Gulliver's Travels*) had satirized in the 18th c. This led to the development of the chronometer, an appliance that could be mechanically used without intellectual effort.

The great Kerala School of Mathematics needs more detailed coverage in the history of Indian science than has been given so far. Both G.G. Joseph and C.K. Raju must be recognized for their valuable contributions in this regard.

Sreni (Guild): A Unique Social Innovation of Ancient India

By Manikant Shah and D.P. Agrawal

Ancient Indian guilds were a unique and multi-faceted form of organisation, which combined the functions of a democratic government, a trade union, a court of justice and a technological institution. The trained workers of the guilds provided a congenial atmosphere for work. They procured raw materials for manufacturing, controlled quality of manufactured goods and their price, and located markets for their sale.

Unfortunately, Eurocentric lens has distorted the Indian guild by equating it with the European feudal or manorial system of the high Middle Ages. , due mainly to sudden increase in trade. These European guilds, identified as Merchant Guilds and Craft Guilds, lasted in some places until the 19th and 20th century, though their golden age probably was in the 13th and 14th centuries. The Craft Guilds were the direct producers and, therefore, more important than the Merchant Guilds. But the Indian guilds were far more important and complex than the European institutions.

The real character and antiquity of ancient Indian guilds have been the subject of some debate.

According to Romila Thapar (2000:73):

> "The ancient sources frequently refer to the system of guilds which began in the early Buddhist period and continued through the Mauryan period. ….Topography aided their development, in as much as particular areas of a city were generally inhabited by all tradesmen of a certain craft. Tradesmen's villages were also known, where one particular craft was centred, largely due to the easy availability of raw material. The three chief requisites necessary for the rise of a guild system were in existence. Firstly, the localization of occupation was possible, secondly the hereditary character of professions was recognized, and lastly the idea of a guild leader or jetthaka was a widely accepted one. The extension of trade in the Mauryan period must have helped considerably in developing and stabilizing the guilds, which at first were an intermediate step between a tribe and a caste. In later years they were dominated by strict rules, which resulted in some of them gradually becoming castes. Another early incentive to forming guilds must have been competition. Economically it was better to work in a body than to work individually, as a corporation would provide added social status, and when necessary, assistance could be sought from other members. By gradual stages guilds developed into the most important industrial bodies in their areas.
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> "Having arrived at a point when the guilds controlled almost the entire manufactured output, they found that they had to meet greater demands than they could cater for by their own labour and that of their families; consequently they had to employ hired labour. This consisted of two categories, the karmakaras and the bhrtakas who were regarded as free labourers working for a regular wage, and the dasas who were slaves. Asoka refers to both categories in his edicts when he speaks of the bhatakas and the dasas. Thus by the Mauryan period the guilds had

> developed into fairly large-scale organizations, recognized at least in the northern half of the sub-continent if not throughout the country. It would seem that they were registered by local officials and had a recognized status, as there was a prohibition against any guilds other than the local co-operative ones entering the villages. This suggests that a guild could not move from one area to another without official permission."

Thapar explains that work distribution depended on (1) the available professionals and (2) the in living in the town but also in terms of the physical occupation by different professions of different parts of the town. Each sreni had its own professional code, working arrangements, duties and obligations and even religious observances. Matters relating to larger dispute were sometimes settled by srenis amongst themselves. Social mobility among such groups, where an entire group would seek to change its ritual status on the basis of an improvement of actual status, would be more frequent, since the economic opportunities for improving actual status would be more easily available, particularly in periods of expanding trade. It is not coincidental that the greatest activity of heterodox sects and of religious movements associated with social protest was in periods of expanding trade (Thapar 1996: 133).

According to U.N. Ghosal Narada prohibits mutual combination and unlawful bearing of arms as well as internecine conflict (????) mutual conflicts among the groups. Brihaspati lays down the extreme penalty of banishment for one who injures the common interest. According to Katyayana, one committing a heinous crime, or causing a split, or destroying the property of the groups, is to be brought before the King and 'destroyed'.

Interestingly, we are told by Brihaspati, that all members have an equal share in whatever is acquired by the committee of advisers or is saved by them, or whatever they acquire through the King's favour, or whatever debts are incurred by them for the purpose of the group…The evidence of the late Smriti law of guilds is corroborated in part by certain types of clay-seals, which, have been recovered from the excavations of Gupta sites at Basarh (ancient Vaisali) and Bhita (near Allahabad). These seals bear the legend nigama in Gupta characters (Bhita) and more particularly the legends sreni-kulikanigama and sreni-sarthavaha-kulika-nigama (Basarh). These names are often joined with those of private individuals. This is a probable reference to the conventions or compacts made by local industrial and trading groups with private individuals or individual members. Such documents would be called sthitipatras or samvitpatras in the technical sense of the late Smritis (Ghosal 1997: 603-607).

Recently, Kiran Kumar Thaplyal (2001) claimed that both Merchant Guilds as well the Craft Guilds were very much present and played a vital role in the socio-economic structure of ancient India. He discusses the institution of the Guilds in four time periods: 1) The Vedic period, 2) Buddhist/Jain period, 3) Mauryan period and 4) and the Post-Mauryan period. Thaplyal sketches a brief historical review and discusses various aspects of the laws, apprenticeship, structure, offices, accounts and the functions of these guilds. He also shows the relationship between the guild and the state. Reference is made to the cobblers' guild, the oil millers' guild, potters guild, weavers' guild, and hydraulic engineers' guild.

The Gautama Dharmasutra (c. 5th century BCE) states that “cultivators, traders, herdsmen, moneylenders, and artisans have authority to lay down rules for their respective classes and the king was to consult their representatives while dealing with matters relating to them.” The Jataka (Buddhist) tales refer to eighteen guilds, their heads, localization of industry and the hereditary nature of professions. The Jataka stories frequently refer to a son following the craft of his father. Often, kula and putta occur as suffixes to craft-names, the former indicating that the whole family adopted a particular craft and the latter that the son followed the craft of his father. This ensured regular trained manpower and created more specialization. The hereditary nature of profession in Indian guilds makes them different from the European guilds of the Middle Ages whose membership was invariably based on the choice of an individual. But it must be pointed out that adopting a family profession in India was more common with members of craftsmen's guilds than with members of traders' guilds.

Before the Buddhist/Jain period, Vedic society was sufficiently advanced to warrant the existence of such economic organizations. Terms, like sreni, puga, gana, vrata in Vedic literature indicate guild organization and sreshthi refers to the president of a guild. However, some scholars dispute this. The division of labour under the varna system may have led to the emergence of guild organization. Agriculture, animal husbandry and trade, the three occupations of the Vaisyas, in course of time developed as separate groups. In the Upanishads (c. 6th century BCE) there are several pieces of evidence regarding the existence of guilds in that period.

The Mauryan period is highlighted by the extensive treatment Kautilya gave to Guilds. He who considered the possibility of guilds being centres of power. The Mauryan Empire (c. 320 to c. 200 BCE) saw better maintained highways and increased mobility of men and merchandise. The state participated in agricultural and industrial production. The government kept a record of trades and crafts and related transactions and conventions of the guilds, indicating state intervention in guild-affairs. The state allotted guilds separate areas in a town for running their trade and crafts. The members of the tribal republics that lost political power due to their incorporation in the extensive Mauryan Empire took to crafts and trades and formed economic organizations.

The decline of the Mauryan Empire (c. 200 BCE) led to political disintegration and laxity in state control over guilds, allowing the guilds a better chance to grow. The epigraphs from Sanchi, Bharhut, Bodhgaya, Mathura and the sites of western Deccan refer to donations made by different craftsmen and traders. Guilds of flour- makers, weavers, oil-millers, potters, manufacturers of hydraulic engines, corn-dealers, bamboo-workers, etc. are mentioned in the epigraphs. This period witnessed closer commercial relations with the Roman Empire in which Indian merchants earned huge profits. The evidence of the Manusmriti and the Yajnavalkyasmriti shows an increase in the authority of guilds in comparison to earlier periods. Epigraphic evidence of the period refers to acts of charity and piety of the guilds as also their bank-like functions.

The Guild's laws on organization, production, fixation of prices of commodities, and so on, were based on customs and usage. The state generally recognized these rules. The laws were a safeguard against state oppression and interference in guild affairs. The Gautama Dharmasutra requires the king to consult guild representatives when dealing with matters concerning the guilds. In Kautilya's scheme, a Superintendent of Accounts kept a record of the customs and transactions of corporations. Manu recommends that the king banish any guild member who breaks an agreement. According to Yajnavalkya, guild members had to share profits and losses in proportion to their shares. In the Mahabharata, there was no forgiveness for breaking guild laws. Yajnavalkya prescribes severe punishment for embezzlement of guild property. He prescribes a penalty for anyone who fails to deposit in the joint fund, money obtained for the corporation: the penalty was eleven times the sum that should have been paid. The guild rules helped the guilds to function smoothly and to create stronger bonds of unity in the membership.

Guilds had three components: (a) the General Assembly, (b) the Guild Chairman or the Head, and (c) the Executive Officers. Each had its well- defined sphere of jurisdiction.

(a) The General Assembly

All the members of the Guild constituted the General Assembly. Jataka stories give round figures of 100, 500, or 1000 as members of different guilds. There is a reference to 1000 carpenters of Varanasi under two heads. This could be because the large number was seen as making the guild unwieldy. On the other hand, there are a few references to 1000 members of a guild, without division. The Nasik Inscription of the time of Nahapana refers to two weavers' guilds at Govardhana (Nasik). Mention of bickering within large Guilds is not infrequent and it is possible that a place had more than one Guild of the same trade.

(b) The Guild Head

The head of a guild is often referred to as the jetthaka or pamukkha in early Buddhist literature. Often he is addressed, first in terms of the occupation, then the guild of which he was the head, e.g. 'head of garland makers' (malakara jetthaka), 'head of carpenters' guild' (vaddhaki jetthaka), and so on. Apparently the Guild Head exercised considerable power over the members of his Guild. Setthis were merchant-cum-bankers and often headed merchant guilds. The guild head could punish a guilty member even to the extent of excommunication. Ancient texts do not seem to specify whether the office of the head of a guild was elective or hereditary, though there are positive references to both. It appears that, normally, headship of a guild went to the eldest son. Succession is mentioned only after the death of the head and not in his lifetime, which would suggest that the head remained in office for life. For example, two Damodarpur Copper-plate inscriptions of the 5th century CE show that a man named Bhupala held the office of nagarasreshthi for well over half a century.

(c) Executive Officers

To assist the guild head and to look after the day-to-day business of the guild, Executive Officers were appointed. The earliest reference to Executive Officers is found in the Yajnavalkyasmriti. Their number varies according to need and circumstances.

Yajnavalkya says that they should be pure, free from avarice and knower of the Vedas. It is not specially stated whether the Executive Officers were elected by the Assembly or were nominated by the guild head.

Besides keeping the members of a trade together like a close community, the Guilds undertook many useful functions such as administrative, economic, charitable and banking. The guilds had great administrative control over their members. One of their prime concerns was providing a congenial atmosphere for their members. They procured raw materials for manufacturing, controlled quality of manufactured goods and their price, and located markets for their sale. Arthasastra does not contain any reference to guilds loaning money to the general public, yet there are references suggesting that the king's agents borrowed from guilds on the pretext of procuring various types of merchandize. This shows that guilds loaned money to artisans and merchants as well. Guilds established their efficiency and integrity, and epigraphic evidence shows that not only the general public, but also the royalty deposited money with them. Of the two Nasik Inscriptions (2nd century CE) one records the endowment of 2000 karshapanas at the rate of one percent (per month) with a weavers' guild for providing cloth to bhikshus and 1000 karshapanas at the rate of 0.75 percent (per month) with another weavers' guild for serving light meals to them. The guilds did charitable work to alleviate distress and undertook works of piety as a matter of duty. They were expected to use part of their profits for preservation and maintenance of assembly halls, watersheds, shrines, tanks and gardens, as also for helping widows, the poor and the destitute.

In addition to these functions, Guilds could try their members for offences according to their own mores, which almost assumed the status of law. A guild member had to abide by both guild and state laws. The Vasishtha Dharmasutra accepts the evidence of guilds as valid in settling boundary disputes. However the jurisdiction of guild courts was confined to civil cases alone. All guilds acted as courts for their members. Only important guilds, or representatives of state authorized guilds, had the power to act as courts for the general public. Guilds were organizations of people of different castes following the same profession.

Caste and guild were basically different. Guilds were economic institutions while castes were social groups. Whereas caste might have been hereditary, the guild membership was not so. One could be a member of more than one guild. However, in areas populated by people of the same caste, membership of guild and caste coincided and the head of the guild presided over the meetings of both guild and caste.

Guilds inherently enjoyed considerable autonomy, and not from any state patronage. The guilds protected the interests and legal rights of traders and craftsmen from any state oppression. Manu required the king to be cognizant of the laws of the srenis and other institutions when dealing with them. Yajnavalkya said, those rules of corporations that are not against sacred laws should be observed. Even Kautilya, a champion of state control over all spheres of activity, laid down rules for protecting the artisans. Since the state earned a sizable income from taxing guilds, it naturally provided them with necessary infrastructure like maintaining roads for transporting merchandise. It also gave them subsidies and loans.

As members of the guild some of the prosperous merchants might have financially supported the king in times of emergency. Kings honoured guild heads by offering gifts. Guild heads were present at important state ceremonies. The heads of guilds accompanied Suddhodana in welcoming the Buddha, and visited the Buddha along with Bimbisara. According to tradition they, along with others, waited for the coronation ceremony of Bharata, and accompanied Bharata to visit Rama at Chitrakuta. The naigamas participated in Rama's coronation ceremony.

There is no evidence of a guild or a combination of guilds attempting to capture political power. The guilds of the period were local in character, with no central organization. The guilds had different interests, some even conflicting, making it unlikely that would present a unified front against the state. However, in case succession to kingly power was contested, then they might have helped their chosen candidate. Kautilya advises the king to ensure that heads of different guilds did not unite against him, and to win their support through reconciliation and gifts, and to weaken those who were his enemies. He also advises the king to grant land, which wass under attack from an enemy, to the guild of warriors. Guild quarrels, both internal and external, provided the king with appropriate opportunities to interfere in guild affairs. Yajnavalkya enjoins that a king should settle quarrels among guilds according to their usages and make them follow the established path.

Many social institutions that we generally attribute to the ingenuity of the West were already present in the socio-economic structures of ancient Indian society.

Indians had made these unique social innovations which served a variety of useful functions: specialisation of crafts, quality control of products, defence against state's oppression, composing differences among different sections of society, providing justice to the needy, charity to the poor and so on. Guilds were perhaps the earliest democratic institutions of the world.

International Conference on Indigenous Indic Traditions in Forestry: Lessons for Contemporary Sustainable Forest Management

Infinity Foundation has long been committed to the development of Traditional Knowledge Systems (TKS), especially those that have modern applications. This commitment was honored when it sponsored the first *"International Conference on Indic Traditions in Forestry: Lessons for Contemporary Sustainable Forest Management,"* held on February 8-10, 2001 in Bhopal, India. Infinity Foundation worked in cooperation with the International Network on Ethno-forestry, the Indian Institute of Forest Management, and Deep N. Pandey in the planning of the event.

Participation was open to historians, Indologists, natural resource managers, educationists and development practitioners from around the world. Foresters actively working with indigenous knowledge in forestry and ethno-forestry were also invited. This diverse group worked together to overcome those barriers that either continue to hamper the revival of India's TKS or prevent the integration of these TKS with formal sciences.

The conference also explored the empirical evidence across cultures and nations to substantiate the claim that when indigenous knowledge, institutions and strategies are combined with their modern scientific counterparts, the result is far more productive than previously assumed.

History of Indian Forestry Traditions

India has a long history of forestry traditions. Indeed, these traditions predate the documentation of known sources of Indic traditions. These traditions existed in the Vedic period, later Vedic period and later were recorded in Puranic literature. In fact, one can refer to the Vedic references as the theory, and the later Vedic and Puranic literature as the practical application. Subsequently, these ancient and proven traditions guided Indian foresters. Most importantly, these traditions still continue to survive and continue to be practiced by modern traditional foresters.

An instance of the continuity from Vedic to modern forestry techniques is the relationship between tree groves and water tanks known as talabs. From the Rg-vedic period through Puranic times, descriptions of various trees groves and talabs in India exist. In the 5th century CE, Varahamihira wrote, in detail, on the tank-tree relationship. Such writings and their prescriptions were considered sacred and the forester had the ethical duty to adhere to them, since they benefitted the entire society.

The effect of this particular prescription was and still is amazing. A total of 1.53 million village tanks built from 2000 BCE onwards still survive in India today. These tanks vary in size from 0.5 ha (hecta-acres) of water harvesting area for the maintenance of a grove of a few trees to several hundred hecta-acres in order to serve a very large grove.

The indigenous knowledge of local forests, known as ethno-forestry, provides another vivid example of the continuity of Indic forestry science. Several references can be found in such texts as the Vedas, Upanishads, the Mahabharata, the Ramayana, the Arthasastra, and the Brihatsamhita on the role that forests and trees play and how to manage resources required by Indian forests.

It is crticial to analyze these accounts of ethno-forestry in India, not just in the context of the history of forest management, but also in the context of contemporary relevance. This knowledge could then be applied to the indigenous forests in present-day India.

If India chooses to pursue a path towards sustainable development, it must understand that modern science cannot offer a complete solution to the various problems associated with such a goal. India must revive and support its own traditions that have also stood the test of time and are still relevant.

In fact, the revival of such traditions in several areas in India has already proven very successful. Diverse examples suggest that the revival has resulted in the sustainable forestry and livelihood security.

The World Bank on Equity of Knowledge

In response to growing concerns on the marginalization as well as the appropriation by the West of global TKS, the World Bank devised a framework regarding equity of knowledge systems in 2000. This framework rested on the fact that equity of knowledge systems should provide Empowerment, Security, and Opportunity to those that belong to the tradition:

1. Equity of knowledge as Empowerment: This can be understood as making the state institutions pro-people and pro-people's knowledge, thereby reducing the social barriers to participation and enhancing the capacity of the poor to make choices to address the livelihood security and sustainability.

2. Equity of knowledge as Security: By making productive use of collective wisdom of formal and traditional sciences we shall be able to help the poor to manage the risks they face because of the destruction of resource-base and societal hindrances.

3. Equity of knowledge as Opportunity: The process of using formal strategies in the access, transmission, integration and field application of indigenous knowledge and Indic traditions is promising. It can enhance the productivity and efficiency of context specific developmental interventions for attacking the poverty and addressing the sustainability of natural resources.

Topics Addressed at the Conference

The Conference explored five basic questions:

1. What are the indigenous Indic traditions in forestry? This includes indigenous water management and harvesting techniques.

2. What is the history of the neglect and destruction of these traditions?

3. How are these traditions reflected in the contemporary Indian landscape? This can include various enthno-forestry practices such as sacred groves, sacred gardens, home gardens, tanks and trees, community-conserved landscapes, etc.

4. How can society benefit from Indic Traditions in order to achieve the objectives of sustainable forest management? In other words, how can equity of knowledge be achieved between the local communities possessing the indigenous knowledge and formal forestry scholars? How does the World Bank's framework of Empowerment, Opportunity, and Security apply?

5. What are the contemporary examples of integration of Indic traditions with modern forestry? What is the relationship between TKS and Intellectual Property Rights?

Seminar on Traditional Knowledge Systems
4-7 October 2002
Binsar, Uttaranchal Pradesh, India.

Driven by its vision to develop the Traditional Knowledge Systems (TKS) of India, Infinity Foundation initiated and funded a seminar on in October of 2002. It was held at the mountain resort town of Binsar (elevation 7000') near Almora, in the hilly state of Uttaranchal Pradesh. The seminar drew a wide variety of scholars who brought a diverse and interesting mix of topics to the discussion. It was a critical springboard to the initiation of the HIST book series.

List of Papers Presented

1. "Traditional Knowledge Systems, Science, and Globalisation" by Pawan K. Gupta
2. "Traditional Indian Iron Technology: Problems and Prospects" by Vibha Tripathi
3. "Traditional Knowledge, History, Science, and Culture" by CK Raju
4. "Traditional Knowledge Systems and Uttaranchal" by DP Agrawal
5. "Native Categories of Thought and World-View" by Nita Mathur
6. "Traditional Hydrology: Some Illustrations from Vedic Science" by JS Rawat and Geeta Rawat
7. "Ayurveda as Praxis" by Ramashray Roy
8. "Traditional Sustainability: Reviving Community Water Management in the Himalayas" by Ravi Chopra
9. "Standing Firm: Traditional Aseismic Architecture in the Western-Central Himalayas" by Rishiraj Das
10. "Traditional Building Techniques: Material and Process" by RC Agrawal
11. "Ethno-medico-biology of Some Common Ailments in Uttaranchal Himalaya" by Vijay Prasad Bhatt
12. "The Stone Axe Tradition in India Pre- and Proto-history" by Shanti Pappu
13. "Traditional Methods of Conservation of Fodder Plants in Kumaun Himalaya" by Hema Joshi
14. "Folklore Biomedicine for Some Veterinary Diseases and Disorders in Western Part of Almora District, Uttaranchal, India" by Rohita Shah, PC Pande, Lalit Tiwari, and Lok Vigyan Kendra
15. "Himalayan Medicine Sytem (HMS)" by Lalit Tiwari and Lok Vigyan Kendra
16. "Craftsman as Mythmaker" by Shampa Shah
17. "Developing Uttaranchal: the Traditional Options" by Ila Sah, Manikant Shah, and Lok Vigyan Kendra
18. "Folk Science in the Folklore of Uttaranchal" by Alakhanth Upreti
19. "Role of Informatics in Traditional Knowledge Systems" by Durgesh Pant
20. "Traditional Knowledge in Environment Management: a Participatory Approach" by Reema Pant
21. "Tradition of Iron Making and the Role of Central Himalayas" by Jeewan S. Kharakwal
22. "Ecological and Technological Knowledge of Hunter-Gatherers in India: Some Examples" by VN Misra and Malti Nagar

Annual Meetings of Infinity Foundations HIST Project

The first meeting of Infinity Foundation's project on History of Indian Science and Technology was held in December 2003 in Delhi. It was sponsored by the Infinity Foundation and organized by Smt. Krishan Bisht of Mahila Haat at India International Center New Delhi. The following scholars participated in the meeting:

1. D.P. Agrawal
2. Rajiv Malhotra
3. C.K. Raju: Traditional Indian Concept of Time
4. Vibha Tripathi: Ancient Iron Technology
5. Purushottam Singh: History of Agriculture in India
6. Rima Hooja: Traditional Hydraulic Technology
7. Charu Gupta: Textile Technology
8. J.P. Joshi : Harappan Civil Engineering
9. Balasubramaniam: Ancient Iron Technology
10. J.S. Kharakwal: Zinc Production in Ancient India

The second meeting of the HIST project was also organized at India International Center in January in Delhi in 2004, and was attended by the following scholars:

1. D.P. Agrawal: Harappan Technology.
2. J.S. Kharakwal: Ancient Zinc Production in India
3. J.P. Joshi: Harappan Civil Engineering
4. C.K. Raju: Traditional Indian Concept of Time
5. Vibha Tripathi: Ancient Iron Technology
6. Rima Hooja: Traditional Hydraulic Technology
7. Charu Gupta: Textile Technology
8. Sharda Srinivasan: Wootz Making in India.
9. Balasubramaniam: Ancient Iron Technology
10. J.S. Kharakwal: Zinc Production in Ancient India
11. Sheela Tirpathi: Ancient Ship Building in India.
12. Jayant Kalawar, representing Rajiv Malhotra

The meeting was also addressed by Prof. MGK Menon and Dr. Kapila Vatsyayan.

The third annual meeting was organized by Balasubramaniam at IIT Kanpur in January 2005. It was attended by the following scholars:

1. D.P. Agrawal: Harappan Technology.
2. J.S. Kharakwal: Ancient Zinc Production in India
3. J.P. Joshi: Harappan Civil Engineering
4. V.S. Shinde: Chalcolithic Technology
5. Vibha Tripathi: Ancient Iron Technology
6. Pankaj Goyal: Traditional Hydraulic Technology
7. Balasubramaniam: Ancient Iron Technology

7. J.S. Kharakwal: Zinc Production in Ancient India
8. Pranab Chattopadhyaya: History of Archaemetallurgy in Eastern India.

This meeting was also attended by eminent archaeologists like M.C.Joshi, who presented a concept note on Science and Technology in the First millennium BCE. Dr. R.S. Bisht presented a paper on Harappan Hydraulic Engineering. J.P. Joshi and R.S. Bisht delivered public lectures to students and teachers.,

List of Bibliographies
List of DYKs
List of Store is placed in the website.

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